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PHYSICAL FLOW CHARACTERISTICS
OF THE
ST. CLAIR RIVER
IN THE VICINITY OF
THE CHEMICAL VALLEY
AND IN
CHENAL ECARTE

APRIL, 1987

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Ontario
Ministry
of the
Environment

J. Bishop, Director
Water Resources Branch

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PHYSICAL FLOW CHARACTERISTICS
OF THE ST. CLAIR RIVER
IN THE VICINITY OF
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IN CHENAL ECARTE

by

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April, 1987

98

TABLE OF CONTENTS

Page

FOREWORD... iii

SUMMARY OF FINDINGS.. iv

CONCLUSIONS.. ix

RECOMMENDATIONS.. xi

INTRODUCTION... 1

MATERIALS AND METHODS.. 3
    Locations.. 3
    Equipment and General Procedure............................ 7

RESULTS.. 10
    Data Summary... 10
    Measurement Difficulties................................... 12

ANALYSIS OF THE RESULTS.. 18
    Upper St. Clair River Area................................. 18
    Chenal Ecarte Area... 28

ACKNOWLEDGEMENTS... 35

REFERENCES... 36

APPENDIX I - Chronological Summary of Conducted Measurements................................ 37

APPENDIX II - Statistical Summary of Current Meter Measurement Results.................... 40

APPENDIX III - Summary of Drogue Measurement Results........... 52

FOREWORD

This study was conducted to provide the necessary flow-characteristic data, in support of ongoing Ministry of the Environment (MOE) programs. These programs are aimed at developing and using various predictive methods to quantify both the spatial and temporal variation of industrial effluent effects upon the St. Clair River system.

Study emphasis was focused on the upper St. Clair River between the Cole Drain outlet and the southern tip of Stag Island, and on Chenal Ecarte from its inlet to the Sydenham River, to determine the significance of different daily wind conditions upon current velocities and travel times (and thus the transport of chemicals discharged to the river).

Study findings will be used in investigating the transport of chemicals discharged to the river; specifically, there are three major applications which include: the development and use of various predictive techniques, to be employed for impact-assessment within the St. Clair MISA modelling work; the production of the "St. Clair River Spill Manual," for assessment of the spill impact upon the Wallaceburg and Walpole Island water intakes; and for specific outfall impact assessments in support of Regional requests.

RÉSUMÉ

Les données recueillies au cours de cette étude indiquent les variations de la vitesse du courant et des temps de parcours, en fonction du vent, à deux endroits du réseau de la rivière St. Clair. Les mesures sur place ont été effectuées à partir de plusieurs débits quotidiens de la rivière (de 6 400 à 7 100 m^3/s). Les résultats obtenus donnent des renseignements sur la direction et le temps de parcours de l'effluent entre les exutoires Cole Drain et Dow 1st St., et Stag Island. On trouve également le temps de parcours entre l'embouchure du chenal Ecarte et la prise d'eau de Wallaceburg et des évaluations des débits à l'embouchure des chenaux Ecarte et Johnston.

Les données recueillies sont utilisées pour les modèles qu'élabore la Section des Grands Lacs et qui déterminent le sort des produits chimiques et la façon dont ils sont transportés. Ces modèles quantifient les variations spatiales et temporelles des effets de l'effluent industriel sur le réseau de la rivière St. Clair.

SUMMARY OF FINDINGS

This study provides data which reflect both qualitatively and quantitatively, the variation of current speed and travel time in two study areas, under different daily wind conditions. The location of these two areas are shown in Figure 1. The major daily wind directions not covered in the data are SW for the upper St. Clair River study area, and E for the Chenal Ecarte study area.

Currents were measured at different lateral locations and depths, along ten separate river sections, (5 sections in each study area). The location of these river sections are provided in Figures 2 to 4. In addition, drogues were released at particular locations at some of the river sections to determine travel times and paths.

The mean daily discharge of the St. Clair River ranged from 6430 to 7110 CMS [2], for the six different days on which current speeds and/or travel times were measured, within the upper St. Clair River study area.

A summary of average current speeds measured in the upper St. Clair River study area, is provided in Table 1. Mean current speeds ranged from 8 to 117 cm/s at 1 m from the water surface and from 29 to 84 cm/s near the river bottom.

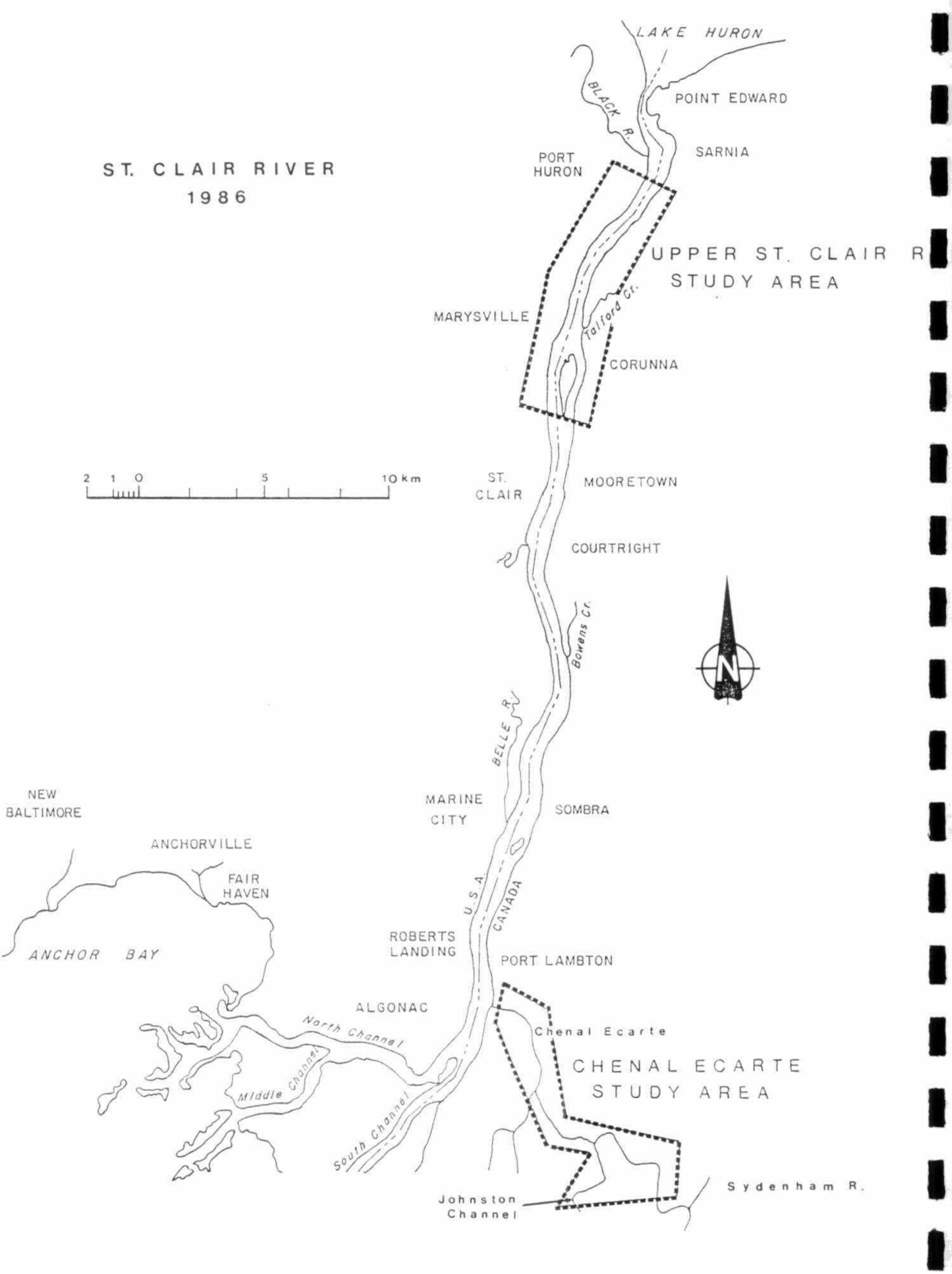


Fig. 1: Location of Study Areas

TABLE 1:
Summary of Average-Current Speeds in the Upper St. Clair Study Area

Section No. Location	Distance from shore (m)	Measured Water Depth (m)	Measured-Average-Current Speed (cm/s)		Average Current Speed Near Bottom
			1 m from surface	0.5 m from bottom	Average Current Speed Near Surface
I- Northern boundary of Polysar	100	10. -12.	109 - 123	73 - 77	.62 - .62
	40	7. -10.	73 - 100	57 - 64	.57 - .71
	10	1.5- 3.0	8 - 34	-	-
II- Southern boundary of Polysar	100	11.	112 - 139	80	.58
	40	7.5- 8.	35 - 59	33	.56
	10	2.5- 4.5	13 - 33	29	.89
III-Cdn. Side at the Southern boundary of Dow	100	10.5	118	78	.66
	40 - 60	8.5- 9.5	65 - 88	63	.72
	15 - 20	6.5	52 - 59	42	.80
III-U.S. Side at the Southern Boundary of Dow	100	10.	100	67	.67
	40	7.5- 8.0	86 - 87	65	.75
	10	5.5	57	-	-
IV-Cdn. Side at the Southern Boundary of Suncor	100	10. -11.	109 - 119	71 - 85	.65 - .71
	40 - 50	10.	83 - 86	63	.73
	10	8.	42	-	-
IV-U.S. Side at the Southern Boundary of Suncor	100	10. -10.5	88 - 104	62	.59
	40	10.	81 - 94	57	.60
	10	5. - 6.	41 - 60	37	.90
V- at middle of Stag. Is. on east side	mid-channel	8.5	116 - 117	81 - 84	.69 - .73
	1/4 width-E.	11.	114 - 116	69 - 75	.60 - .66
	1/4 width-W.	8.	113 - 114	78 - 80	.69 - .71

From analysis of the current meter and drogue measurement results, the other findings for the upper St. Clair River study area, are summarized as follows:

i) Although some of the variance in average current speed at the 10 and 40-m from shore stations was due to flow-depth variance (due to location inaccuracies), the impact from daily wind change appeared to be relatively more significant in these 'shallower'locations, as compared to the deeper 100 m from shore locations.

ii) The dimensionless vertical velocity profile at a given station tended to remain the same under the different daily wind (and total river discharge) conditions.

iii) The range of travel time for drogues released at the Cole Drain outlet to reach the southern-end of Stag Island was 2.3 to 2.5, and 2.6 to 3.6 hours, at depths of 1 and 6 to 7 m, respectively.

iv) The travel times for drogues released 40 m from shore at the First Street outfall complex to reach the southern-end of Stag Island was 2.2 to 2.3 and 2.5 hours, at depths of 1 and 6 m, respectively.

v) The daily changes in travel time tended to directly reflect the daily total river discharge rate changes, and were consistent with measured current speeds.

vi) For drogue releases at 40 and 100 m from shore (at the 3 and 7 % total-river discharge streamlines), the travel paths remained within 200 m of shore between Cole Drain and the southern-end of Stag Island, (within the 18 % streamline). At the southern-end of Stag Island, the individual drogue locations varied from about 30 to 200 m from shore, (between the 1 and 15 % streamlines), with no clear daily wind relationship.

The mean daily discharge of the St. Clair River ranged from 6570 to 6810 cms [2], for the three different days on which travel times were measured within the Chenal Ecarte study area. It ranged from 6570 to 7030 cms [2], for the four different days on which current speeds were measured in the same area.

A summary of the study findings for the Chenal Ecarte study area are:

i) About 4% (+/- 1%) of the total St. Clair River flow entered Chenal Ecarte.

ii) The flow entering Chenal Ecarte required from 5.3 to 5.8 hours on average to reach the Johnston Channel junction under the different daily wind conditions.

iii) At the Johnston Channel junction, around 60 to 80% of the 'upper' Chenal Ecarte flow entered Johnston Channel, and the other 20 to 40% entered the 'lower' Chenal Ecarte.

iv) The flow which entered the lower Chenal Ecarte required from 3.0 to 4.6 hours to reach the Wallaceburg water intake location.

v) The total travel time for the flow entering Chenal Ecarte (at the St. Clair River) to reach the Wallaceburg water intake, ranged from 8.3 to 10.4 hours.

vi) Current speeds across the width of the lower Chenal Ecarte immediately downstream from the Johnston Channel junction, were considerably more variable as compared to the other locations studied.

vii) The value of average current speed 1 m from the surface and near mid-channel for Secs. VI, VII-A, VII-B, VII-C, and VIII, ranged from 41 to 54, 40 to 53, 13 to 33, 51 to 54, and 23 cm/s, respectively. These speeds corresponded closely to the average drogue speeds.

CONCLUSIONS

The results may be used to approximate the behaviour of effluent discharges originating from Canadian sources along the upper St. Clair River, namely the Cole Drain and Dow outfalls.

The behaviour of the effluent from the Cole Drain outfall may best be determined using the results from the Section I drogues, (which were released virtually at the outfall itself). Depending on the wind condition (and corresponding total river discharge), the mean travel times of the effluent between the outfall and Section V (near the middle of Stag Island), is around 1.9 +/- 0.1 hours. For the effluent confined to the bottom 1 m of the river, the travel time is about 2.4 +/- 0.4 hours.

The 'average center' of the Cole Drain effluent plume does not vary greatly from the 7 to 8 % total-river streamline location, between Secs. I and III. However its 'streamline deviation' increases further downstream from Sec. III, up to +/- 5 % near the middle of Stag Island.

The behaviour of the effluent from the Dow near-shore-based outfalls are more difficult to approximate, since the closest drogue releases to shore were 40 m away, (since closer deployments would have caused collisions with docks, and created boat safety problems). As indicated by a previous MOE study [4] (which uses field measurements of chloride from Dow's 4th Street sewer), the near-shore-based outfall plumes are centred typically from 10 to 40 m from shore, in the river reach between Section II and the middle of Stag Island. In addition, the present study has shown that the measured current speeds may be used relatively accurately to predict travel times. Therefore the 10 and 40 m from shore current measurements are used to estimate the range in average travel speeds and times for the plumes. The results indicate that the range of average travel speed and time, due to both daily total-river discharge and vertical location variations, are from 27 to 51 cm/s, and 4.5 to 8.6 hours, respectively.

The 'average center' of the Dow near-shore-based outfall plumes varies between the 0 and 10 % total-river discharge streamlines, by the time they reach the middle of Stag Island. This is estimated using the average 40-m drogue paths as an 'outer limit'.

The portion of a plume, from any of the above-mentioned outfalls, within the 4% (+/- 1%) of the total St. Clair River flow nearest the Canadian shore, enters Chenal Ecarte. The plume then takes from 5.3 to 5.8 hours on average, to reach the Johnston Channel junction. At this point, around 60 to 80 % enters Johnston Channel, and the other 20 to 40 % remains in Chenal Ecarte. The portion of the plume which remains in Chenal Ecarte takes another 3.0 to 4.6 hours on average, to reach the Wallaceburg water intake location.

Both the largest percentage of the plume which remains in Chenal Ecarte downstream of the Johnston Channel junction, and shortest travel time between the junction and the Wallaceburg water intake, occurs under S to SW wind conditions.

RECOMMENDATIONS

Based upon the results obtained and data gaps identified during this study, future studies are recommended and should incorporate the following components:

i) Repetition of the measurements under a greater number of daily wind conditions, (especially under SW, which is the statistically most common), to increase and better understand the range of results.

ii) An increase in the total current sampling period at the stations to provide a stronger statistical confidence in the results.

iii) An intensified current measurement grid inside of the 40-m lateral locations between Sections I and IV on the Canadian side of the St. Clair River, (in conjunction with dye or other Lagrangian measurements), to better define this area nearest the major shore-based outfalls, which this study has shown to be relatively more variable.

iv) Travel time measurements from the outfall locations down to the St. Clair delta region, to confirm the estimates made in other studies.

v) The use of accurate lateral-distance measurement devices, for work in the near-shore areas of the St. Clair River and Chenal Ecarte, where the depth gradient in the lateral direction is large.

INTRODUCTION

Current Ministry of the Environment (MOE) programs are attempting to develop and utilize various predictive methods to quantify both the spatial and temporal variation of effluent effects on the St. Clair River. These methods will be used in the development of effluent criteria, and in providing a predictive tool in the event of a spill. The complexity of these methods range from simple dilution estimates based only upon field data, to complex numerical fate and transport models to predict water, sediment and biota impact. However all of these methods require basic field measurements which indicate the spatial and temporal variation in the characteristics of the flow in the river. In particular, it is important to measure current velocities at various lateral locations at different longitudinal sections in the river, for use in Eulerian hydrodynamic modelling. Also, the travel times between sections in the river are necessary information for Lagrangian spill assessment.

This study was conducted to extend the existing flow-characteristics database for use in other studies, (eg. the St. Clair River Spill Manual and MISA modelling). As such, this report focuses on the components of the field work, and pursues only a preliminary analysis of the measured results.

The general objective of the study is to provide data which can ascertain the significance of different daily wind conditions upon current velocity and travel time, within two study areas of the St. Clair River system.

The 'upper St. Clair River study area' and 'Chenal Ecarte study area', which are located as shown in Figure 1, were focused on in this study. The upper St. Clair River study area exhibits the greatest environmental impact from the various industrial outfalls of major concern. It is therefore important to provide hydrodynamic data in this area essential for establishing effluent criteria. Within the Chenal Ecarte study area, it is important to learn more about the flow-characteristics for both water-column spill-impact assessment upon the Wallaceburg water intake, and for long-term contaminant fate and transport concerns within the St. Clair River delta.

MATERIALS AND METHODS

Locations

The 'upper St. Clair River study area' is located within the upper portion of the St.Clair River between the Cole Drain outlet and the southern tip of Stag Island, concentrating on the Canadian side.

A total of five river sections were selected for use in measuring current velocities and travel times in this area, and are shown in Figs. 2 and 3. They are Section:

I) the northern boundary of Polysar, near the Cole Drain outfall,
II) the southern boundary of Polysar near the Dow-First Street outfall complex,
III) the southern boundary of Dow Chemical Ltd.,
IV) the southern boundary of Suncor, and
V) along transect SR-30.1e, within the channel east of Stag Island near the ferry-dock.

The 'Chenal Ecarte study area' includes Chenal Ecarte between its St. Clair River inlet and the Sydenham River, with emphasis at the Chenal Ecarte-Johnston Channel junction.

A total of five river sections were used in measuring current and travel times in this area and are shown in Fig. 4. They are Section:

VI) Across Chenal Ecarte, about 500 m downstream (east) from the St. Clair River.
VII-A) Across Chenal Ecarte, about 100 m upstream (west) from the north-west corner of the Chenal Ecarte - Johnston Channel junction.

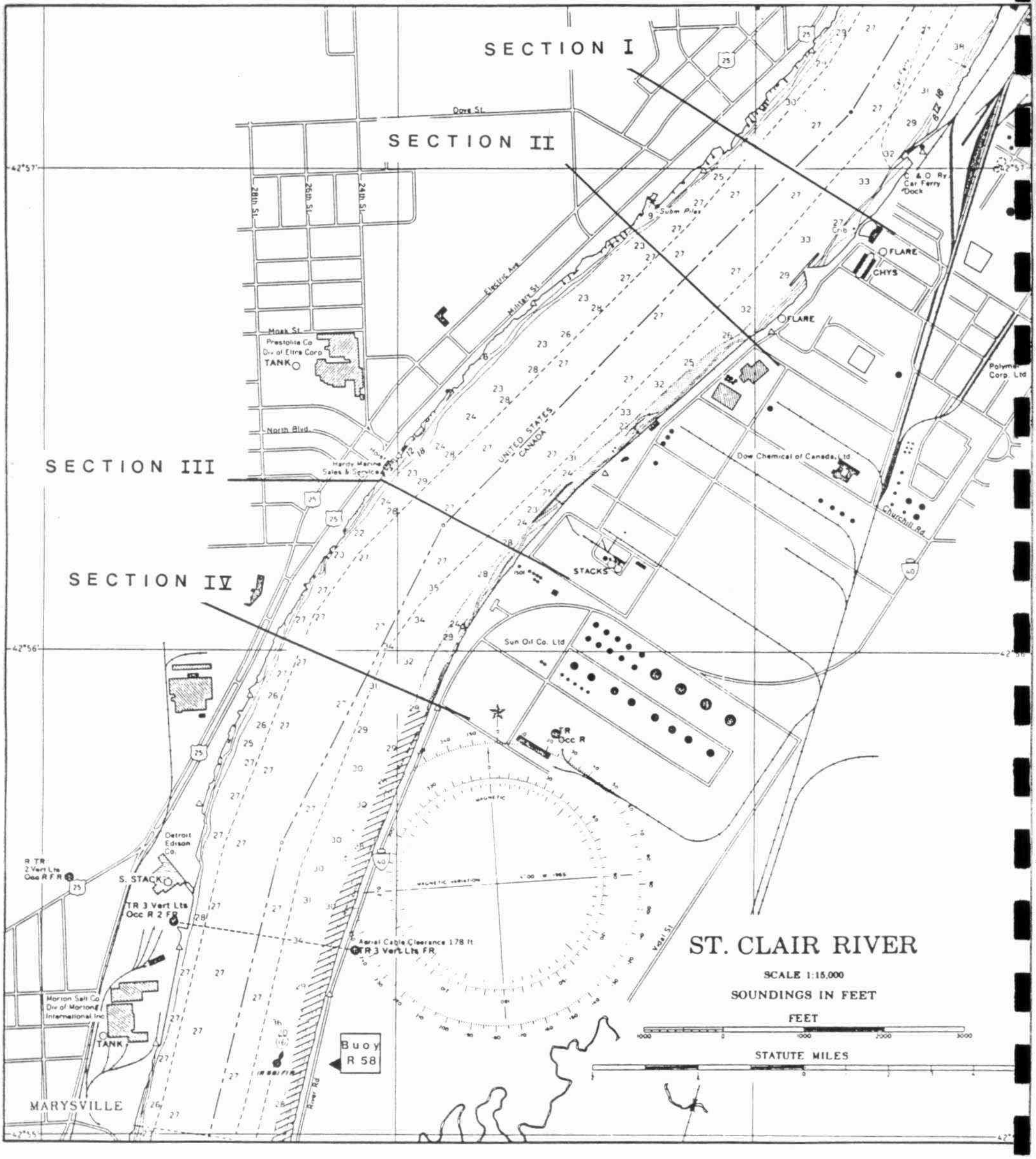


Fig. 2: Locations of Sections I to IV

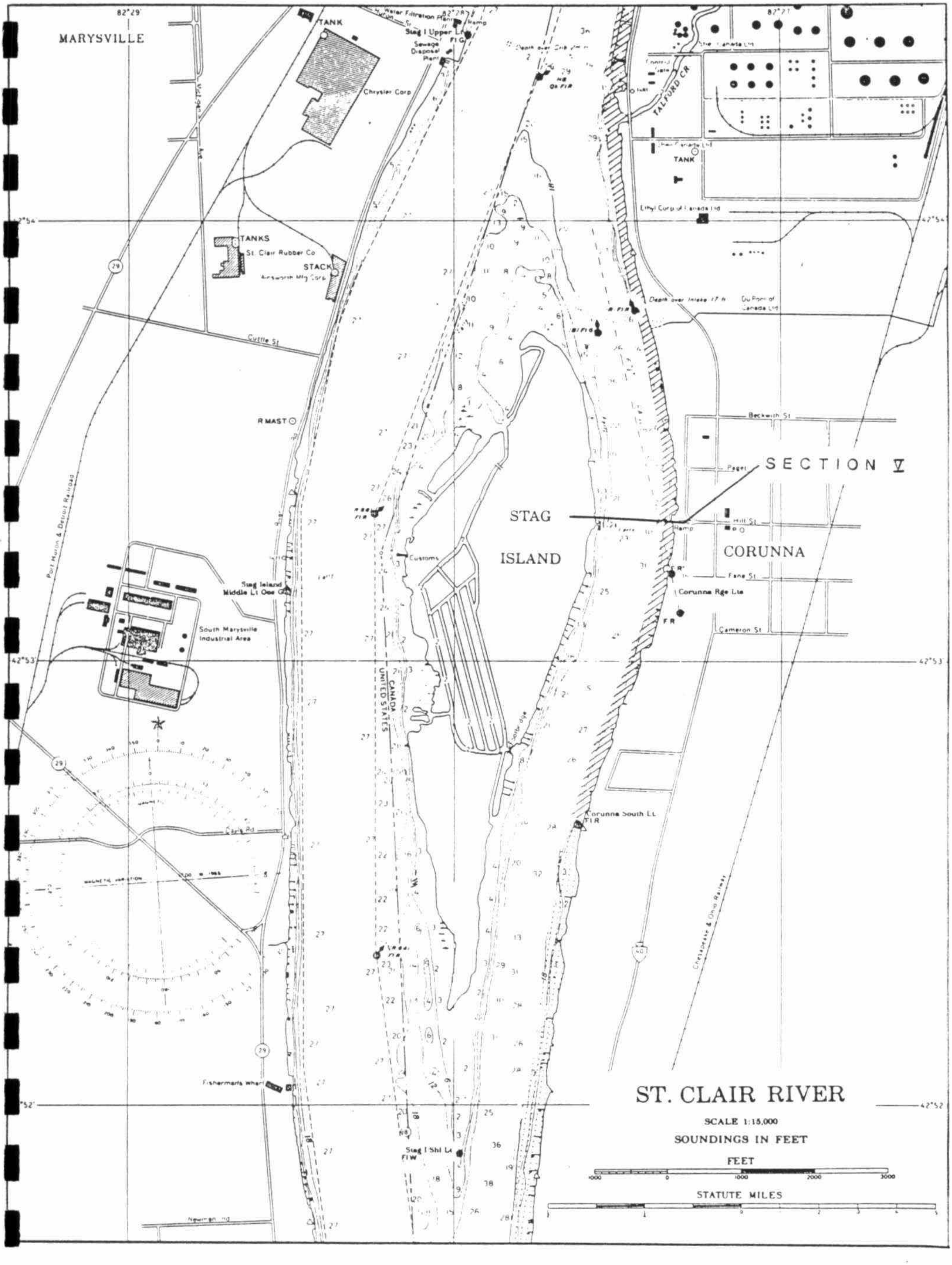
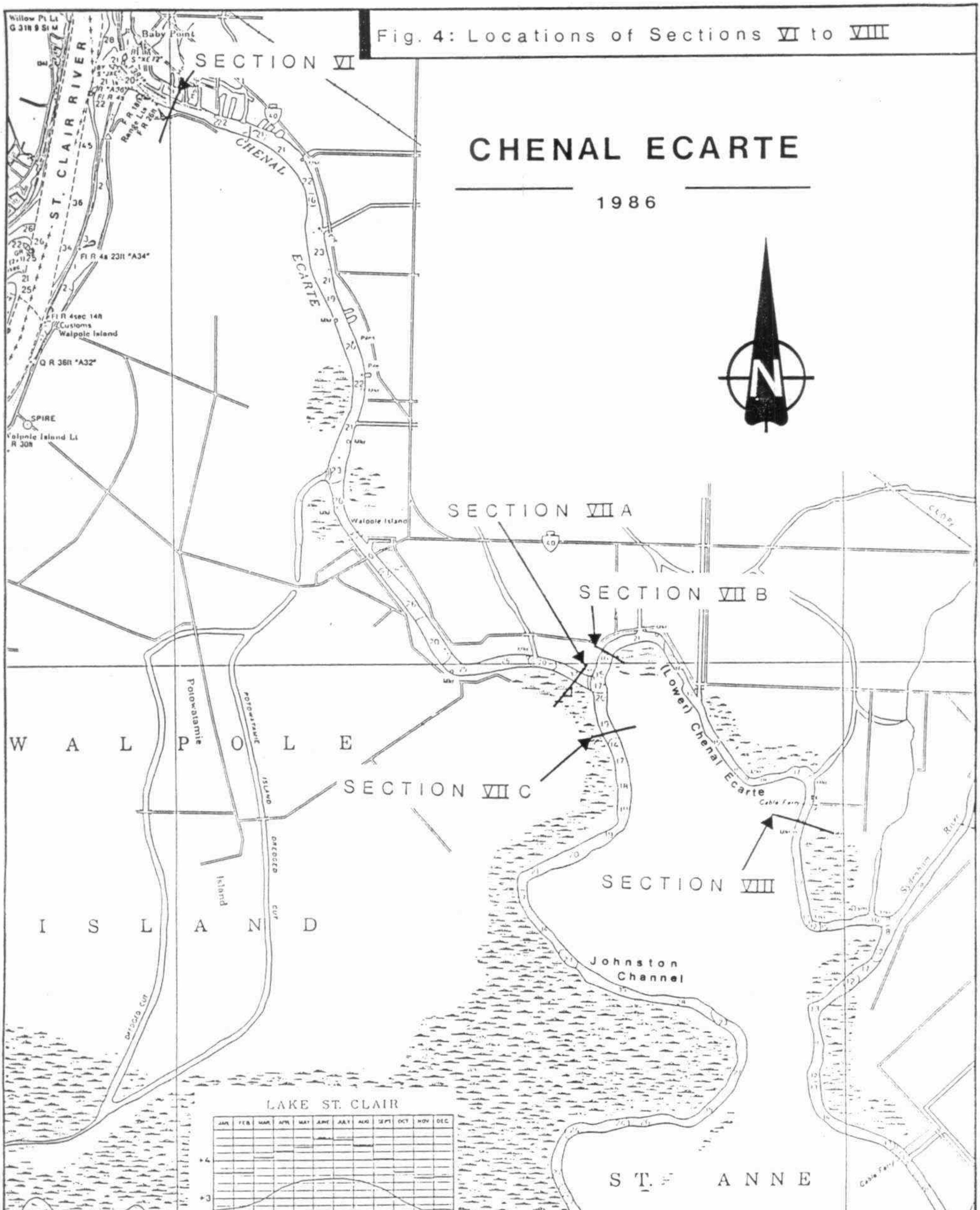


Fig. 3: Location of Section V

Fig. 4: Locations of Sections VIII to VIII



VII-B) Across Chenal Ecarte, about 200 m downstream (north) of the north-west corner of the Chenal Ecarte-Johnston Channel junction.

VII-C) Across Johnston Channel, about 400 m downstream (south from the south-west corner of the Chenal Ecarte-Johnston Channel Junction, and

VIII) Across Chenal Ecarte, about 200 m downstream (south) from the cable-ferry crossing near the Wallaceburg water intake.

Equipment and General Procedure

Current Measurements:

Current measurements were made using the Anderaa Model RCM4 current meter, which is a mechanical (vertical-axis rotation) meter.

Current velocities were measured at distances of about 10, 40, and 100 m from the Canadian shore, at Sections I through IV. They were also made at similar distances from the U.S. shore for Sections III and IV. Measurements were made at locations of 1/4, 1/2, and 3/4 of the total channel width, for Section V. For all of these locations, the velocities were measured at both 1 m from surface and 0.5 m from bottom. They were also measured at mid-depth for the 100 m and mid-channel locations.

Within the Chenal Ecarte study area, current velocities were measured at locations of 1/4, 1/2, and 3/4 of the total channel width, for all 5 sections. For all of these locations, the measurements were made at 1 m from surface, 0.5 m from the bottom, and at mid-depth for the mid-channel locations.

The sampling interval selected for use by the self-recording current meters, was determined by the time constraints imposed, and the number of meters available for the study. It was not practical to measure both of the study areas in one day. For the upper St. Clair River study area, there were 7 sub-sections to measure (5 Canadian and 2 U.S.), each with 3 lateral locations and at least 2 vertical depths. By deploying 2 meters, this meant at least 21 separate sample locations had to be measured. Thus to meet daily time constraints, the maximum sampling period was set to 20 minutes per location. To provide a minimum of 15 readings per location, the sampling interval of the meters was set to 1 minute.

The 3 meter-measured parameters recorded for the study include current speed, current direction, and water temperature. The current speed is calculated in cm/sec, and represents an average value over the sampling interval. The accuracy of the values are the greater of +/- 1 cm/sec or +/- 2 % of the speed.

The current direction is calculated as bearing angle from magnetic north, and represents an instantaneous value. The accuracy of these values are +/- 5 degrees for current speeds of 5 to 100 cm/sec, and +/- 7.5 degrees for other current speeds.

The temperature is calculated in degrees C with a 63 % response time of 12 seconds. The accuracy of these values are +/- .05 degrees C.

Travel Time Measurements:

Travel times were determined using 1 meter-square canvas drogues. Using travel distances estimated from navigational charts [1], travel speeds were also calculated.

In the St. Clair River study area, drogues were released from two locations. The first was at the Cole Drain outfall (about 68 m from shore at Section I). The second was near the Dow First Street outfall complex, about 40 m from shore. For both of these locations, drogues were released both 1 m from surface and about 1 m from bottom (about 6 to 7 m depth).

For the Chenal Ecarte study area, drogues were released from mid-width of Section VI, at both 1 and 3 m depths. (The 3 m depth was selected by adding 1 to 2 m to the minimum depth along the travel path recorded in the navigation chart [1]). Drogues were also released at the 1/4, 1/2, and 3/4 width locations of Section VII-A, at 3 m depths. Other drogues were released at 1 and 3 m depths from mid-width of both Sections VII-B and VII-C.

Wind Measurements:

Wind measurements were made at least once per section, using a hand-held aenometer, for a period of 10 to 20 seconds during typical wind conditions. This was usually done while anchored at the 100 m distance from shore or mid-width locations. The estimated accuracy in wind speed and the direction bearing angle are +/- 25 % and +/- 30 degrees, respectively.

Depth measurements:

After anchoring for current measurements, the water depth was estimated using an echo-sounder. The current meters were placed vertically via winch or rope with an estimated accuracy of +/- 0.5 m.

Depth Cross-Sections:

For Sections VI, VII-A, VII-B, and VII-C, the depth cross-sections were estimated using the Si-Tex HE-106 recording echo-sounder.

Station Locations:

The downstream locations of the various river sections were easily identified using shore-based references. An estimated accuracy for anchoring at these sections would be +/- 20 m.

The lateral distances from shore were visually estimated with an estimated accuracy of +/- 15 %. Radar was used for checking the larger sampling distances at Section V.

Total-River Flow Characteristics:

Pertinent reference material for total river flow rates and lake levels during the study period is provided in Table 2. These data originate from NOAA in the U.S. [2,3].

RESULTS

The St. Clair River Physical Study was conducted during two separate periods. The first was the week of April 21/86, with measurements made during 5 non-consecutive days. Measurements were also made during another 4 day period starting on July 29/86. A chronological summary of the measurements taken during the two periods is provided in Appendix I.

During the second sampling period only 1 current meter was available for use. As a result, to permit measurements of all sections of the 2 study areas, the total sampling period of a current meter deployment was reduced from 15 or 20 to 8 or 10 minutes. Thus to provide at least 15 readings per deployment, the sampling interval was reduced from 1 to 0.5 minutes.

Data Summary

Current Meter Measurements:

After eliminating the erroneous recordings, a total of 2906 useful records remained from the 8 days of current measurements.

A statistical summary (mean, standard deviation, maximum, and minimum) is provided for each deployment in Appendix II, for the three meter parameters measured (current speed in cm/s, current direction in magnetic bearing degrees, and water temperature in degrees C). Appendix II uses the following priority in listing the results: Section number, date, distance from shore, and meter depth. The measured wind conditions taken from the boat are also provided in Appendix II. The 'from' wind direction is given in bearing degrees from true north.

TABLE 2
St. Clair River Flow Rates and Adjacent Lake Levels During the Measurement Time Period

a) Average daily conditions:

DATE	Total St. Clair River Discharge Rate [2] (cms)	Boat measured winds	
		Direction from	Speed (Knots)
April 21	6820	NW to NNE	5 to 10
" 22	6810	NW to NNW	6 to 14
" 23	6570	SSW to WNW	0 to 6
" 24	6290	(SW)	
" 25	6560		
" 26	6430	NE to SE	10 to 12
" 27	6440	SE	6 to 10
July 28	6870	(SW)	
" 29	7110	W to NW to N	3 to 8 to 12
" 30	7030	W to NW	0 to 10
" 31	6810	S to SW	0 to 9
August 1	6940	NW to NE	3 to 10

b) Average monthly conditions:

MONTH	Total St. Clair River Discharge Rate [3] (cfs)	Water Surface Elevations [3] (ft. above mean 1955 Father Point Datum)	
		Lake Michigan-Huron at Harbor Beach	Lake St. Clair at St. Clair shores
March	208,000	580.40	576.17
April	221,000	580.75	576.21
May	224,000	580.89	576.25
June	226,000	581.07	576.51
July	231,000	581.27	576.56
August	231,000	581.34	576.47

Drogue Measurements:

A total of 23 drogue deployments were conducted during 6 different days of the study. A summary of the measurements for travel path, time, and speed, is provided in Appendix III.

The drogue-tracking locations are shown in Figures 2, 3 and 5, for the upper St. Clair River and Chenal Ecarte study areas, respectively.

Depth Cross-Sections:

The cross-sections were recorded for Sections VI and VII on two occasions, (July 30 and 31). An average of the 2 results are shown as Figs. 6 through 9.

From the 2 results per section, the approximate average depth accuracy is +/- 0.75, 0.75, 0.25, and 0.50 m respectively, for Sections VI, VII-A, VII-B, and VII-C.

Measurement Difficulties

It was not always possible to measure currents at the planned lateral locations for the various sections, because of the time constraints and anchoring difficulties. On August 1, most of the 10 m distance from shore stations (on the St. Clair River) were not measured because of the dangers imposed by the rough-water conditions.

Some difficulties encountered which may effect the interpretation of both the current speed and direction results, include:

i) Lateral 'drift-rotation' about the anchor-point, due to cross-winds and weak water currents at:

   a) Section I, 10 m from shore on April 21
   b) Section VI, on April 22
   c) Section VII-C, at 30 m from the east shore on April 23.
   d) Section VIII, at 10 m from east shore on April 23.

Fig. 5: Drogue Tracking Locations

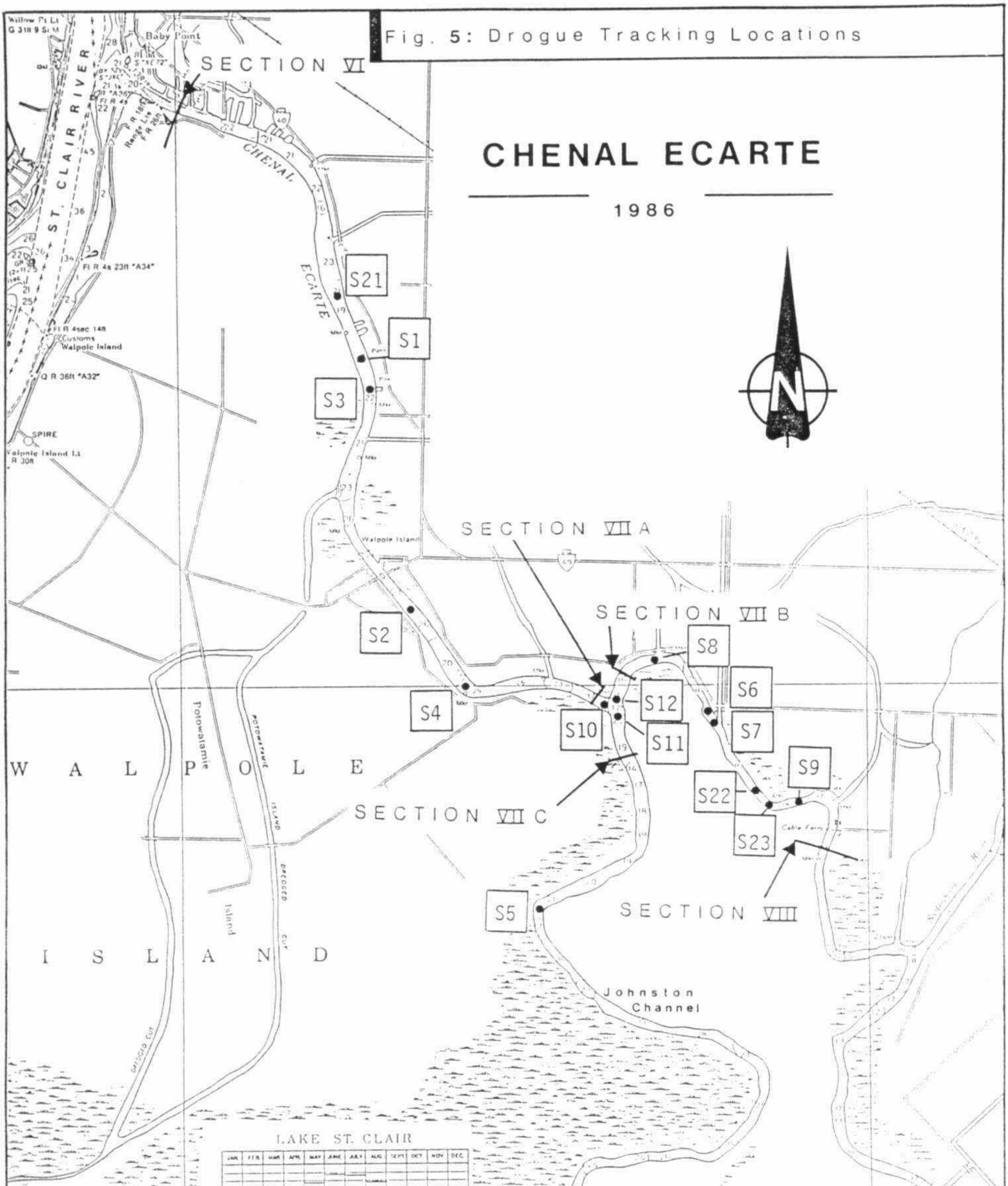


Fig.6 : SECTION VI - CROSS-SECTION

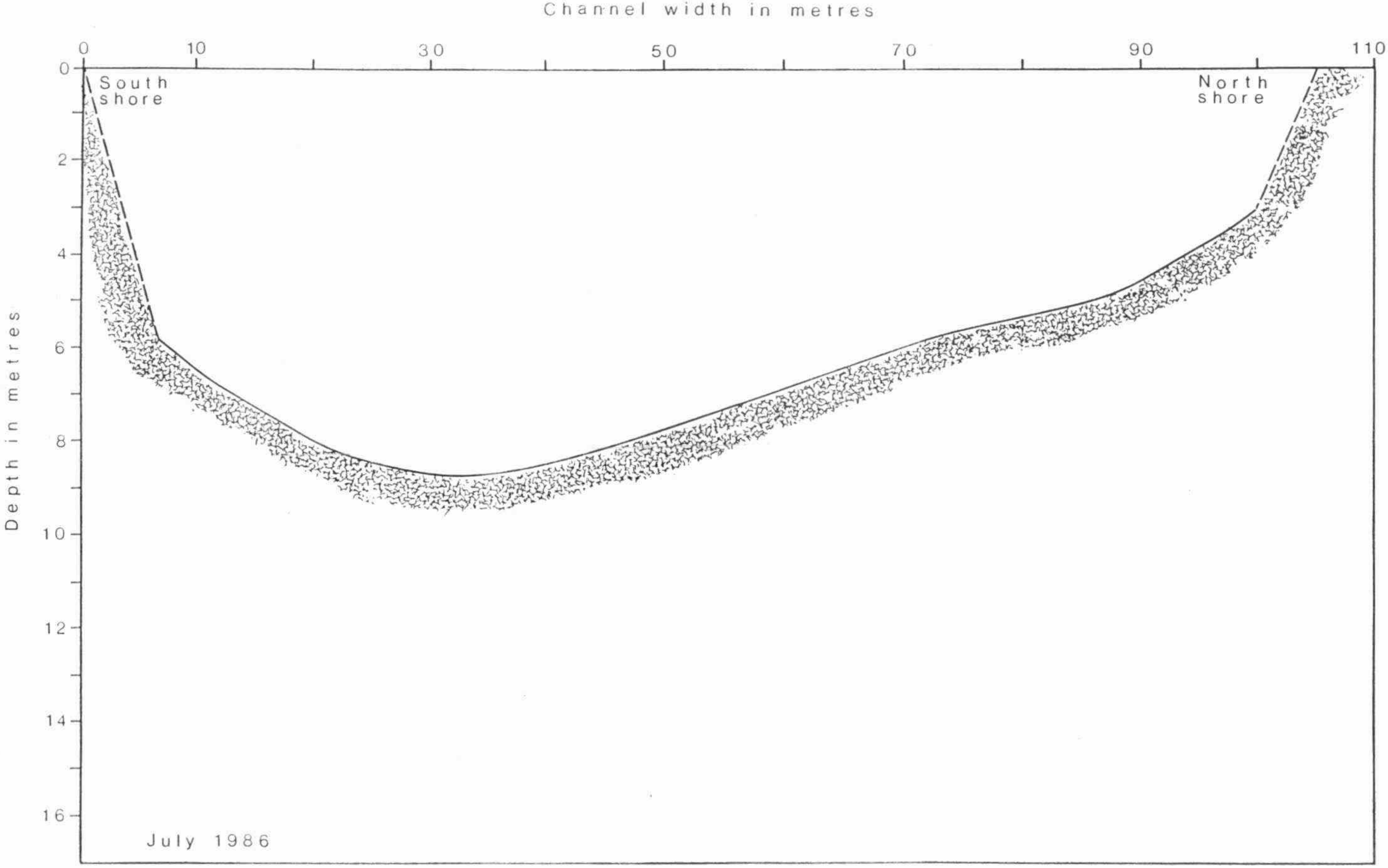


Fig. 7 : SECTION VIIA - CROSS-SECTION

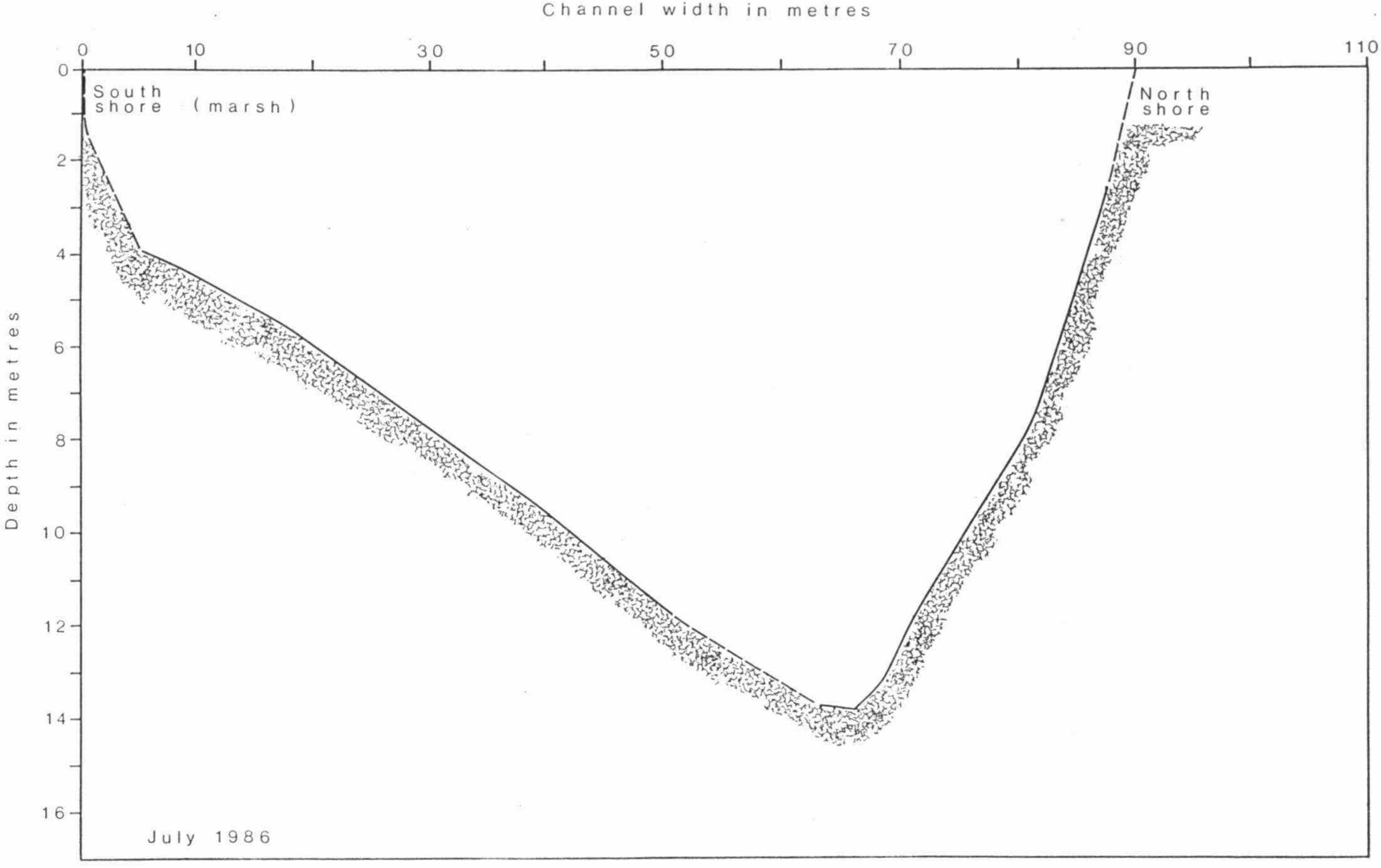


Fig. 8 : SECTION VII B - CROSS-SECTION

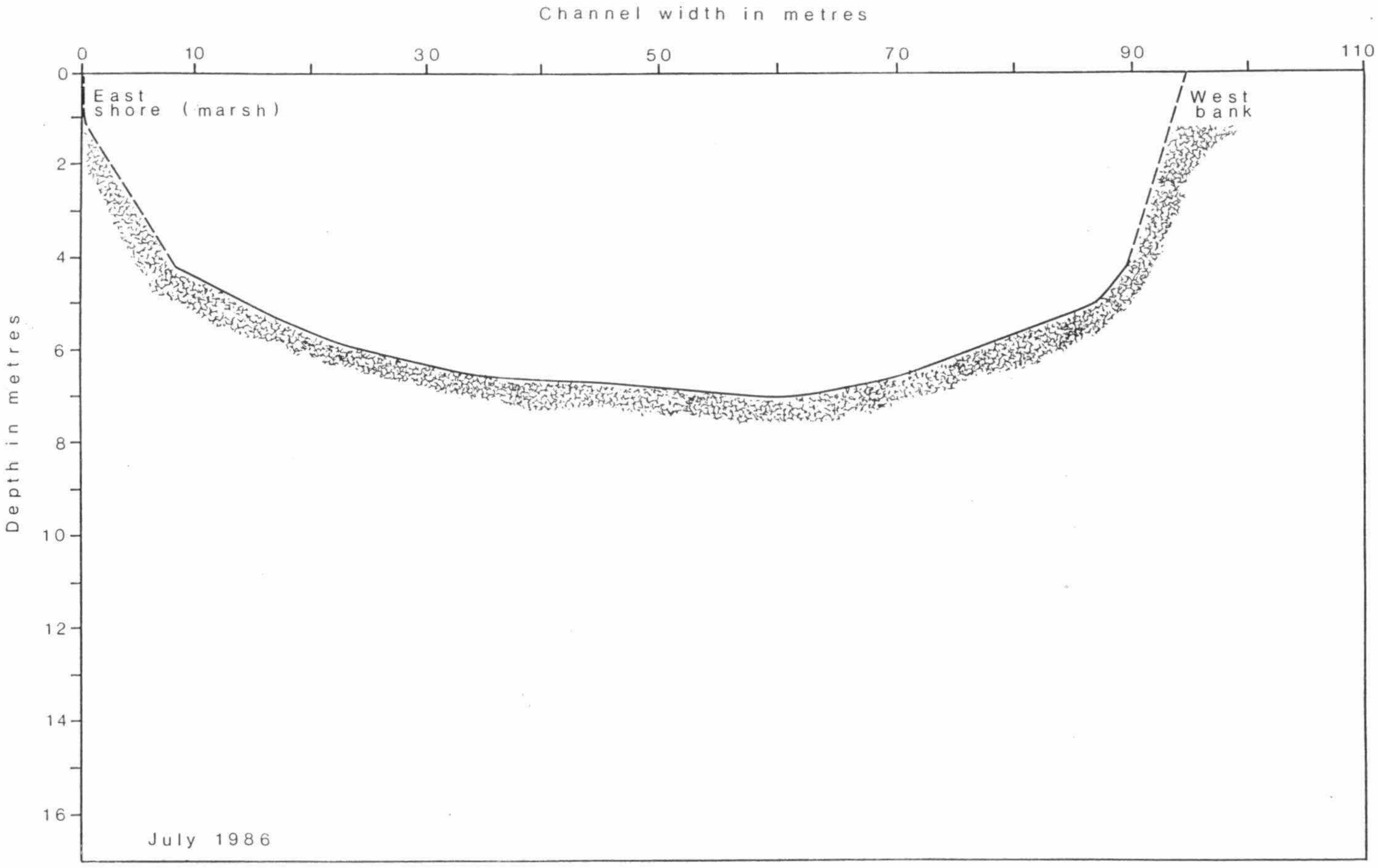
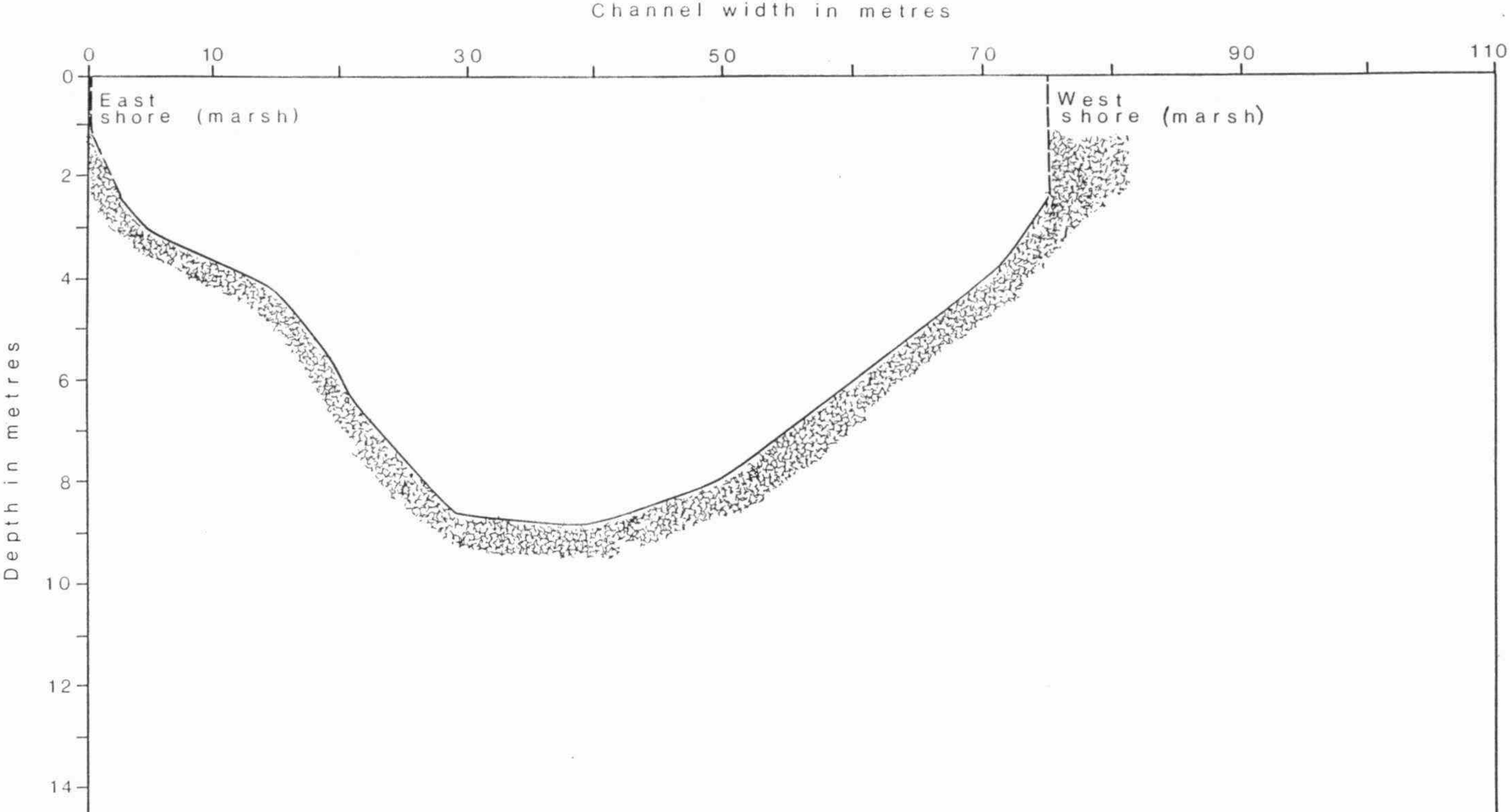


Fig. 9 : SECTION VIIC- CROSS-SECTION



ii) Rough water conditions on the Canadian side of Section III, due to wave reflections off the vertical sheet-piling of the bank. This was noted on both measurement dates (April 21 and August 1).

Some concern was also raised about the lower drogue deployment from Section I on July 29 and Section II on July 29 and 30. As indicated in Appendix III, it was suspected that the bottom of the drogues were 'dragging' along the river bed in some locations. This would tend to increase the travel times, and might introduce a false lateral movement in the drogue path.

ANALYSIS OF THE RESULTS

As discussed earlier, only an preliminary data analysis is conducted, since the data results will be used and discussed in other projects.

Upper St. Clair River Area

Current Meter Data:

There are three average wind directions covered in the 4 days of measurements taken, (N on April 21 and August 1, E on April 26, and WNW on July 29). Looking at the Appendix II data for all of these dates, there is a significant (no overlap of mean +/- standard deviations) trend of reduction in mean current speed, moving from surface to bottom or from the 100 to 10 m locations, (as is expected approaching the boundaries). Inversely, there is usually an absolute increase in the size of the standard deviation of the speed for the same locational variations.

To provide a relative comparison, the current speeds are divided by the 100 m or mid-channel surface speeds on all dates when these were measured, in Table 3.

TABLE 3:
Relative Current Speeds, Using 100-m or Mid Surface Current Speeds as Reference

SECTION NO.	DATE	WIND	Distance from shore (m)	Relative Current Speed (Local Speed/Reference Speed) for Meter Depth			Average Current Speed (cm/s) @ Reference Surface
				Surface	Mid	Bottom	
I	26/04	SE	10	.31			
		10 to 12	40	.67			
			100	1.00			108.7
	29/07	W to NW	10	.06			
		3 to 8	40	.81	.69	.46	
			100	1.00	.90	.62	123.1
	1/08	NW to NE	10	.07			
		3 to 10	40	.77		.55	
			100	1.00	.87	.62	118.1
II	26/04	SE	10	.12			
		10 to 12	40	.31			
			100	1.00			111.7
	29/07	W to NW	10	.24		.21	
		3 to 8	40	.43	.32	.24	
			100	1.00	.86	.58	139.1
III-CDN.	1/08	NW to NE	20	.44		.35	
		3 to 10	60	.75		.54	
			100	1.00	.96	.66	118.1
III-U.S.	1/08	NW to NE	40	.87		.65	
		3 to 10	100	1.00	.91	.67	99.9
IV-CDN	26/04	SE	10	.38			
		10 to 12	40	.76			
			100	1.00			109.1
	29/07	W to NW	10	.12			
		3 to 8	40	.29		.34	
			100	1.00	.93	.65	109.5
	1/08	NW to NE	50	.72		.53	
		3 to 10	100	1.00	.97	.71	118.7
IV-U.S.	26/04	SE	10	.68			
		10 to 12	40	.92			
			100	1.00			87.9
	29/07	W to NW	10	.40		.36	
		3 to 8	40	.90		.54	
			100	1.00	.92	.59	104.2
V	26/04	SE	WD/4-E	.55			
		10 to 12	MID	1.00			111.9
			WD/4-W	.74			
	29/07	N	WD/4-E	.98		.65	
		12	MID	1.00	.95	.73	116.3
			WD/4-W	.98		.69	
	1/08	NW to NE	80-E	.99		.59	
		3 to 10	MID	1.00	.95	.69	116.5
			220-E	.97		.67	

Legend: WD/4-E - means ¼ of the total section width from the east shore.
80-E - means 80 m from the east shore.

Section I: At Section I, the current speed typically ranged by an order of magnitude from the shallow 10 m to deep 100 m surface locations, (eg. from about 10 to over 100 cm/s). Under the WNW and N wind conditions of July 29 and August 1, the current speeds near bottom (0.5 m above bottom) were about 60 % of those near the surface, for both the 40 and 100 m locations.

By comparing the 100 m surface values, there appears to be a significant increase during the WNW and N wind conditions as opposed to the SE condition, (eg. about 120 compared to 109 cm/s). To provide some indication of the degree to which this change is 'localized' (ie. change at this section only) as compared to 'global' (ie. change in total river flow), the ratio of the average current speeds are compared with the daily-mean total river discharge-rate ratios, for the same dates. This analysis is summarized in Table 4.

These results for Section I indicate that most of the change at the 100 m location is accounted for by the 'global' river changes. However, about 2/3 of the change at the 40 m location would represent a 'localized' effect. The current speed here are about 20 % larger under the N to NW winds, compared to the SE wind, after correcting for 'global' effects. The 10 m location results, reveal no pattern largely because of a 'significant depth variation' in station location on different dates, (ie. anchoring inaccuracies are too great to permit a reliable analysis here).

Section II: At Section II, the same type of current speed changes as noted for Section I are observed. It appears that the speed is significantly greater, at least at the 100 m surface location, under the WNW wind at Section II compared with Section I, (139 to 123 cm/s).

Conducting the 'localized-global' analysis as summarized in Table 4, it appears that 'localized' change is significant at all lateral locations, and increases towards the shore. The relative current speed (corrected for 'global' effects) was about 12 and 50% greater under the NW wind as compared to the SE wind, for the 100 and 40 m locations, respectively.

TABLE 4:
Comparison of the relative daily changes in surface-depth current speed and total river discharge rate, (using April 21 or 26 data, as reference)

	DISTANCE FROM SHORE (m)				RELATIVE AVERAGE-CURRENT SPEED AT SURFACE DEPTH LOCATION				RELATIVE MEAN-RIVER DISCHARGE			
DATE	21/04	26/04	29/07	1/08	21/04	26/04	29/07	1/08	21/04	26/04	29/07	1/08
WIND DIR.					N	SE	W	N	N	SE	W	N
SECTION #												
I		100	100	100		1.00	1.13	1.09		1.00	1.11	1.08
		40	40	40		1.00	1.38	1.26				
		10	10	10		1.00	0.24	0.26				
II		100	100			1.00	1.25			1.00	1.11	
		40	40			1.00	1.69					
		10	10			1.00	2.53					
III-Cdn.	15			20	1.00			0.89	1.00			1.02
	40			60	1.00			1.37				
	80			100	1.00			1.01				
III-U.S.	40			40	1.00			1.00	1.00			1.02
	80			100	1.00			1.07				
IV-Cdn.		10	10			1.00	0.30			1.00	1.11	1.08
		40	40	50		1.00	0.38	1.03				
		100	100	100		1.00	1.00	1.09				
IV-U.S.		10	10			1.00	0.69			1.00	1.11	
		40	40			1.00	1.17					
		100	100			1.00	1.19					
V		WD/4-E	WD/4-E	WD/4-E		1.00	1.83	1.86		1.00	1.11	1.08
		MID	MID	MID		1.00	1.04	1.04				
		WD/4-W	WD/4-W	WD/4-W		1.00	1.38	1.37				

Section III-Cdn.: At this section, Table 3 shows that speed variation is not as large due to the deeper waters nearer to shore here (ie. the 15 or 20-m locations average about 55 cm/s or about 45 % of the 118 cm/s speed at the 100-m location. The vertical speed variation is also slightly less with the bottom averaging around 70 % of the surface. The 100-m average surface speeds of near 118 cm/s under the N winds are similar to that for Section I.

Table 4 shows that most of the daily change at the 100-m location is due to the 'global' river change. There does appear to be a large 'localized' effect at the 40 to 60-m locations. Correcting for 'global' effects, current speeds here are 35 % greater for the N wind as for the SE wind. Locational inaccuracies at the 10-m location prevent analysis here.

Section III-U.S.: Under two different N winds of April 21 and August 1, similar current speeds were obtained at this section, (around 95 cm/s at the surface 100-m location). These are lower than the near 120 cm/s value at the 100-m locations of Sections I and III-Cdn.

From Table 3, lateral and vertical speed variation here were around 60 and 70% respectively, compared with the 100-m or 80-m reference surface locations.

Table 4 indicates that the daily changes in current speeds at Section III-U.S. are probably due more to 'global' river changes, as the increase at the 80 to 100-m depths is small and due to different flow-depths on the different dates. Also, there is no relative increase at the 40-m location.

Section IV-Cdn.: At Section IV-Cdn., the current speeds at the 100 m surface location were near 110 cm/s for SE and WNW winds, and increased slightly to near 120 under N winds. The error margin in station location appears significant, as the July 29 depths for the 10 and 40-m locations are much smaller than those for April 26 and August 1. Using the April 26 and August 1 dates only, (SE and N wind, respectively), there was a slight increase in 100-m surface current speeds from 109 to 119 cm/s.

From Table 3, the 10-m location surface speed was about 40 % of the 100-m surface speed on April 26. The speed near bottom was about 70 % of the surface at both the 100 and 50-m locations on August 1.

The station location error margin discussed earlier, makes it difficult to use the results in Table 4, especially for the 10 and 40-m locations. Most of the change at the 100-m location appears 'global' in nature.

Section IV-U.S.: At Section IV-U.S., the 100-m surface speed was significantly higher under the WNW wind of July 29, as compared with the SE wind of April 26, (104 as compared with 88 cm/s). This SE wind current speed was significantly lower than the 109 of Section IV-Cdn., on the same date.

From Table 3, the current speed at the 10-m surface location was about 40 to 70 % of that of the 100-m surface location for the two dates. The bottom speed was about 60 % of the surface for both the 40 and 100-m locations on July 29.

The results from Table 4 indicate a relative 'localized' increase of around 6 % in the current speed at the 40 and 100-m locations, under the N wind, as compared with the SE wind.

Section V: The surface speed at the mid-channel locations were about the same for the SE and N winds of the 3 dates (around 112 to 116 cm/s). The station location error appears significant for the 1/4 and 3/4 width stations on April 26, (as they are shallower as compared with those of July 29 and August 1).

Using the last 2 dates (WNW and N winds), there was little lateral variation in the current speed, with the bottom averaging about 70 % of the surface, for all 3 lateral locations, as shown in Table 3.

Table 4 would appear to indicate an increase at the 1/4 and 3/4 width locations under the NW and N winds as compared with the SE wind. However the magnitude of this increase cannot be accurately quantified because of the station location error of April 26.

Drogue Data from the Section I Releases:

The drogue releases from Section I, at the Cole Drain outlet, occurred on April 27, and July 29 and 30, under SE, NW, and W winds respectively. The total travel time from Section I to the south-end of Stag Island were 148, 136, and 141 minutes, on the three dates, respectively, for the 1-m deep drogues. The corresponding average travel speeds were 1.07, 1.17, and 1.12 m/s. Using an error margin of +/- 2 minutes for the drogue times, this would indicate a slight increase in speed from SE to W to NW wind conditions, of around 5 %. The ratio of daily total-river discharge rate for these 3 dates are 1.07, 1.18 and 1.17, respectively. Thus the differences in travel time are due mainly to the change in the daily total-river discharge rate, (ie.'global' in nature).

The travel times and corresponding speeds, for the three releases at 7, 7, and 6 m depths, from the same location and respective dates, are 215, 183, and 153 minutes, and 0.74, 0.87, and 1.04 m/s. The trend is similar to the 1-m deep releases for the first two lower releases. However, the third drogue released was shallower in depth (6 m), and therefore incurred a significantly faster travel speed.

A summary of the drogue paths (ie. the distances from shore to drogue, as they travel downstream) is provided in Table 5. The drogue numbers used in this table correspond to their order of appearance in Appendix III. Also provided in this table for comparison purposes, are the approximate predicted lateral distance from shore to the locations of 5 and 18 % of the long-term average total river discharge rate of 186,600 cfs. These streamlines were obtained from the University of Windsor/MOE K-E model, (a 2-D finite difference model).

TABLE 5:
Lateral Tracking of Drogue Paths on St. Clair River

DOWNSTREAM LOCATION	APPROXIMATE DISTANCE d/s FROM RIVER HEAD (FT.)	DISTANCE FROM SHORE TO TOTAL RIVER STREAMLINE (m), OF:		DISTANCE FROM SHORE TO DROGUE (m)											
				Section I- Surface			Section I- Bottom			Section II- Surface			Section-II Bottom		
				DROGUE NO./WIND											
		5%	18%	1 SE	2 NW	3 W	4 SE	5 NW	6 W	7 SE	8 NW	9 NW	10 SE	11 NW	12 NW
Section I	22,000	54.	130.	68	70	75	68	70	75						
Section II	24,000	57.	136.	80	70	90 *	80	100	100	40	40	40 **	40	40	40 ***
Section III	28,000	57.	137.	70	70	50	80	70	70	80	50	50	70	50	60
Section IV	30,500	57.	137.	130	60	60	100	70	70	130	60	70		40 **	60
Buoy R58	35,500	61.	128.	150	110	70	70 *	40	50	140	60	50		40	55
South-end shell dock	40,500	78.	169.	130	130	110	40	50	60	110	120	30		70	50
660 m south of south-end shell dock	42,500	136.	236.					*					80	30	
Section V	47,000	74.	190.		150	150		30	50	160	150	150			150
Range Light	47,500	78.	194.	140			50								
South Tip Stag Island	54,000	103.	226.	200	200	200	100	25	50		200	60			200
South Stag Island Shoal Light	56,000	139.	225.							200					

LEGEND:

* moved 20 m outwards
** moved outwards
*** moved 10 m outwards

Under the W wind, the surface drogue travelled closer to shore as compared to the SE wind, especially between Section III and the Shell dock. This trend is not as clear for the lower drogues, although all 3 lower drogues appeared closer to shore at the south-end of Stag Island, as compared with their surface counterparts.

By defining "Flow Panels 1 and 2" as the river volumes from the shore to the 5 % streamline, and from the 5 % to 18 % streamlines, respectively, the results indicate:

i) All drogues were released in Flow Panel 2 (at about the 7 streamline).
ii) The surface drogues remained within Flow Panel 2 the entire distance, except for the W wind drogue between Section III and the Buoy R58.
iii) The bottom drogues remain in Flow Panel 2 upstream of Buoy R58, and moved into Flow Panel 1 downstream from there.
iv) All drogues were between the shore and the 18 % streamline at the south-end of Stag Island.

Section I Drogues versus Current Measurements:

On July 29, current measurements were made at Sections I, II, IV-Cdn., and V. Using the appropriate lateral stations (where current was measured), corresponding to the measured drogue path, an approximate drogue speed may be predicted. The average speeds thus predicted for the surface and bottom drogues are about 96 and 64 cm/s, respectively, (as compared to the measured 117 and 87 cm/s). The underprediction is probably due to the fact that the measured current speeds were linearly interpolated between the 40 and 100-m locations at Sections I, II, and IV-Cdn. in the calculations. A serious dragging problem for the lower drogue is not apparent, since its measured to predicted speed is even larger than that of the surface. (This higher ratio is probably because the path taken by the lower drogue would keep it in 8 to 9 m of water, thereby subjecting it to relatively faster current speeds, as compared to 0.5 m from the bottom).

Drogue Data from the Section II Releases:

The drogue releases from Section II, at the First Street outfall complex, 40 m from shore, occurred on the same dates as for the Section I releases. The winds were also similar, except the July 30 wind shifted more from the NW (from the W) while these drogues were in travel.

For the 1-m deep drogue on April 27, the measured travel time and corresponding speed were 141 minutes and 1.12 m/s respectively, between Section II and the South Stag Island Shoal Light. For the 1-m deep drogues of July 29 and 30, the travel times and corresponding speeds were 138 and 139 minutes, and 1.07 and 1.06 m/s, respectively, between Section II and the south-end of Stag Island.

The change in drogue travel speeds for these drogues do not follow the 'global' total-river discharge rate change, as was the case for the Section I drogues. The reason that the SE wind drogue was slightly faster may be due to the 'farther from shore' path taken, as shown in Table 5, as compared with the NW wind drogues, (even though average current speeds were slower).

For the 3 lower drogues, only the July 30 release made it to the south-end of Stag Island. The travel time and corresponding travel speed were 147 minutes and 1.01 m/s, respectively. The other 2 lower drogues of April 27 and July 29, were pulled near the Shell dock. Their respective travel speeds were 0.73 and 0.84 m/s, below that of the July 30 drogue, largely because of their deeper paths. (The July 29 drogue was raised from 7 to 6 m of depth between Section IV and Buoy R58).

From Table 5 it is seen that under the NW wind, the surface drogue travelled significantly closer to shore, especially between Sections III and the Shell dock area, as compared with the SE winds. Although the data is sparse, a similar trend is indicated for the lower drogues.

In comparison with the predicted flow panels:

i) All drogues were released in Flow Panel 1, (around the 3 % streamline).
ii) All surface drogues were in Flow Panel 2 at Section V.
iii) Two of the lower drogues moved into Flow Panel 2 at or downstream of Section III, with however, no apparent wind connection.
iv) All drogues were between the shore and the 18 % streamline at their last recorded position.

Section II Drogues versus Current Measurements:

Following a similar procedure as outlined for the Section I drogues, approximate predicted speeds for the surface and bottom drogues of July 29 are 78 and 35 cm/s, respectively. (The actual travel speeds from the drogues were 1.07 and 0.84 m/s). As for the Section I drogues, it appears that the linear interpolation of measured current speeds between the 40 and 100-m lateral locations, may underestimate the predicted value. Furthermore, it appears that there was no serious dragging problem for the lower drogue, for the same reasons as stated earlier for the Section I lower drogue.

Chenal Ecarte Area

Travel Times:

The data from the 11 drogue deployments conducted on April 22, 23, and July 31, are used to estimate the total travel times for three river reaches:

i) Chenal Ecarte from its inlet at the St. Clair River to Johnston Channel, a travel distance of about 9.0 km.
ii) Chenal Ecarte from Johnston Channel to the Wallaceburg water intake, a travel distance of about 3.5 km.
iii) Johnston Channel for its first 2.5 km travel length only.

The average current speeds measured at Sections VI through VIII, as reported in Appendix II, are analyzed in Table 6, and are used in comparison with the drogue travel speeds.

Under the NW wind of April 22, the travel time in Chenal Ecarte from the St. Clair River to the Johnston Channel was about 5.8 hours, at a depth of 3 m and near mid-channel, (average travel speed of 0.43 m/s). This travel speed compares well to the measure current speeds of about 41 and 40 cm/s, at the mid-width surface locations of Sections VI and VII-A, respectively. By using the mid depth to surface current speed ratios of 1.03 and .96, as was measured under the W to NW winds of July 30, the estimated mid-depth current speeds would be about 42 and 38 cm/s for Sections VI and VII-A, respectively, on this date. Again, this is similar to the measured travel speed of 43 cm/s.

Under the S to SW wind on July 31, the 3 m deep average drogue speed between Section VI and S21, was 0.47 m/s. Extrapolating this speed for the entire reach results in a travel time of 5.3 hours from the St. Clair River to Johnston Channel. This travel speed compares well to the measured mid-depth and mid-channel current speeds at Sections VI and VII-A of 51 and 47 cm/s, respectively.

Under the calm to slight WNW wind of April 23, the travel time in Chenal Ecarte from Johnston Channel to the Wallaceburg water intake was about 4.6 hours, at a depth of 3 m and near mid-channel, (average velocity of 0.21 m/s). This travel speed compares well with the surface mid-width measured current speed of 23 cm/s at Section VIII. However it is about 70 % greater than the mid-width average surface current speed of 13 cm/s, measured at Section VII-B. The probable reason for this difference is that the surface current speed at this section is typically smaller than the mid-depth value of which the drogue is exposed to, particularly under a W to NW wind as shown by the July 30 results.

Under the S to SW winds of July 31, the travel time in Chenal Ecarte from Johnston Channel to the Wallaceburg water intake was about 3.0 hours at both the 1 and 3 m depths, near mid-channel, (average travel speed of 0.32 m/s). Although there were no Section VIII current speed measurements on this date, the travel speed compares well to the measured mid-depth current speed of 37 cm/s at Section VII-B.

Average travel speeds within the first 2.5 km of Johnston Channel, were 0.46 and 0.41 m/s, under the WNW and SW winds of April 23 and July 31, respectively. These values are about 10 to 15% lower than the mid-channel surface current speeds measured at Section VII-C on the same dates, (53 and 51 cm/s). The cross- sectional area of Section VII-C appears to be somewhat smaller than the reach average.

Section Flow Characteristics:

To provide an approximate flow characterization for Sections VI and VII, average section speeds and discharges are calculated for the different dates on which the currents were measured. These values are shown in Tables 6 and 7.

The average section speed is taken as the arithmetic average of the three (1/4, mid, 3/4 lateral width locations) vertical average speeds. For the 1/4 and 3/4 width locations, the vertical-average speed is assumed equal to the average of the surface and bottom measured average current speeds. For the mid-channel locations, the vertical-average speed is assumed equal to the average of the surface, and the average of the mid-depth and bottom measured average current speeds. The vertical-average speeds bracketed in Table 6, are estimated using obtained vertical-lateral average speed ratios for the same section, as measured under similar wind conditions of July 30 or 31.

The section discharge is given by the product of the average section current speed, and cross-sectional area as estimated from Figures 6 through 9. An approximate relative accuracy for these values may be obtained by comparing the discharge rates of Sections VI, VII-A, and the sum of VII-B and VII-C, for a given date. Using Section VII-A as reference, the differences range from 1 to 14% for the 4 dates, with an arithmetic average of 5%.

TABLE 6:
Relative Current Speeds
for:
Individual Points,
Depth-Average and
Section Average.

SECTION NO.	DATE	WIND	Distance from shore (m)	Relative Current Speed: (Local Speed/Reference Speed) for Meter depth:			Calculated, (or estimated), depth - average speed, relative to reference speed	Average current speed (cm/s) @ Reference Surface	Calculated, section-average speed relative to reference speed	Calculated, section-average speed (cm/s)
				Surface	Mid	Bottom				
VI	22/04	NW to NNW 6 to 14	20-N MID WD/4-S	.73 1.00 1.27			(.70) (.91) (1.09)	40.8	.90	36.6
	30/07	W to NW 0 to 10	(WD/4-N) MID (WD/4-S)	1.00	1.03	.82	(.74) .96 (1.14)	54.2	.95	51.3
	31/07	S to SW 0 to 9	10-N MID WD/4-S	.54 1.00 1.18	.94	.49 .70 .82	.52 .91 1.00	53.7	.81	43.5
VII-A	22/04	NW to NNW 6 to 14	10-N 30-N 15-S	.90 1.00 .81			(.83) (.87) (.71)	39.7	.80	31.9
	23/04	CALM	10-N 30-N 30-S	.84 1.00 .81	.93		(.77) (.87) (.71)	42.6	.78	33.4
	30/07	W to NW 0 to 10	WD/4-N MID 15-S	.97 1.00 .76	.96	.80 .52 .57	.89 .87 .67	52.8	.81	42.8
	31/07	S to SW 0 to 19	15-N 35-N 20-S	1.04 1.00 .80	.89	.77 .63 .60	.91 .88 .70	52.2	.83	43.3
VII-B	23/04	SSW to WNW 0 to 6	20-W 50-W 25-E	.97 1.00 .57			(.77) (1.01) (.52)	12.5	.77	9.6
	30/07	W to NW 0 to 10	25-W MID 10-E	.46 1.00 1.19	1.31	.55 .84 1.14	.51 1.04 1.17	23.2	.91	21.0
	31/07	S to SW 0 to 9	15-W 30-E 10-E	.53 1.00 .91	1.10	.31 .95 .74	.42 1.01 .83	33.2	.75	25.0
VII-C	23/04	SSW to WNW 0 to 6	30-W 35-E 30-E	.97 1.00 .99			(.85) (.92) (.87)	52.9	.88	46.6
	30/07	W to NW 0 to 10	10-W 30-E 15-E	.56 1.00 1.02	.95	.57 .67 .83	.57 .91 .93	54.2	.80	43.5
	31/07	S to SW 0 to 9	7-W MID 12-E	.74 1.00 1.03	.93	.56 .76 .78	.65 .92 .91	50.7	.83	41.9
VIII	23/04	CALM	30-W 40-E 10-E	.56 1.00 .59				23.2		

Table 7:

Calculated Section areas and Discharge Rates, for Sections VI and VII

DATE	MEASURED WIND	Estimated, Average-Discharge rate (cms), for Section:					Average, discharge rate (cms) for upper Chenal Ecarte		Daily Ave. Total St. Clair River Discharge Rate (cms)	Upper Chenal Ecarte % of St. Clair River Discharge Rates	
		VI	VII-A	VII-B	VII-C	VII-B + VII-C	Using Ave. Sec. Speed	Using Max. Sec. Speed		Using ave. Sec. Speed	Using Max. Sec. Speed
April 22	NW to NWW, 6 to 14 knots	234	237				236	313	6810	3.5	4.6
April 23	CALM to SSW to WWN, 0 to 6 knots		248	50	212	262	255	316	6570	3.9	4.8
July 30	W to NW, 0 to 10 knots	328	318	110	197	307	318	401	7030	4.5	5.7
July 31	S to SW, 0 to 9 knots	278	321	131	190	320	306	412	6810	4.5	6.0
Sectional Measurements, (average of July 30, 31): Surface width (m)		105.	90.	95.	75.						
Cross-Sectional area (m^2)		640.	742.	524.	454.						

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MINISTRY OF THE ENVIRONMENT
NOV 18 1987
HAZARDOUS CONTAMINANTS BRANCH

323-4917

October 23, 1987

Dear Sir/Madam:

We are pleased to provide you with a copy of the report entitled:

> "Physical Flow Characteristics of the St. Clair River in the Vicinity of the Chemical Valley and in Chenal Ecarte"

The report provides information on the current speed and travel time in two study areas of the St. Clair River system. Study findings will be used in investigating the transport of chemicals discharged to the river, in support of ongoing programs of the Ministry of the Environment.

Sincerely

J.N. Bishop, Director
Water Resources Branch

By averaging the Section VI, VII-A, and VII-B and VII-C sum, for each date, the average discharge entering Chenal Ecarte from the St. Clair River is estimated as 236, 255, 318, and 306 cms, on April 22 and 23, and July 30 and 31, respectively, as shown in Table 7 . An estimate of the upper limit of the Chenal Ecarte discharge (and thus an estimate of the absolute error in these average values) is obtained by using the maximum average-current speed measured at a section, instead of the average-section current speed. The maximum average current speeds average 144, 125, 145, and 122 % greater that the section-average current speeds, for Sections VI, VII-A, VII-B, and VII-C, respectively.

The average and upper limit discharges for Chenal Ecarte as a percentage of the daily total-river discharge rate for the St. Clair River, are given in Table 7. The average and upper limit percentages are around 3.7 % and 4.7 % for April 22 and 23, and 4.5 % and 5.8 % for July 30 and 31.

By comparing the results of the W to NW wind condition of July 30, with those of the S to SW wind condition of July 31, the following points are observed:

i) There is virtually no change in the average-velocity and discharge within the Chenal Ecarte reach between the St. Clair River and Johnston Channel.

ii) Under the W to NW wind condition, the approximate split of flow discharge percent between Johnston Channel and Chenal Ecarte (east of the junction) was 64 and 36, respectively. Under the S to SW wind, these values shifted to around 59 and 41 %. respectively, which is a change of around 5 % of the total incoming discharge.

iii) Under the near calm conditions of April 23, the approximate flow-split percentage between Johnston Channel and Chenal Ecarte (to the east of the junction), was about 80 and 20, respectively. However, the error margin for this date at Section VII-B is probably larger than for the other dates, as indicated by a large minimum-maximum variation in the current direction readings (in Appendix II). This is due to rotational-drift caused by the weak current.

iv) The relative current speeds tend to be much less stable in Section VII-B as compared with Sections VII-A an VII-C, under the different wind conditions.

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APPENDIX I - CHRONOLOGICAL SUMMARY OF CONDUCTED MEASUREMENTS

DATE	WEATHER	SECTION NO.	APPROXIMATE TIME	CURRENT METER DEPLOYMENTS	DROGUE RELEASES
				Lateral Location : Vertical Depth (m)	Lateral Location : Vertical Depth (m)
Monday, April 21, 1986	Cold-drizzle, light rain, snow showers. Wind: 5 to 10 knots from NW to NNE.	I	9:53	40 : 1, 6.5	-
		"	10:24	10 : 1	-
		"	12:12	75 : 1, 10.5	-
		III-CDN.	12:59	15 : 1, 6	-
		"	13:38	40 : 1, 8	-
		"	14:12	80 : 1, 10	-
		III-U.S.	15:41	40 : 1, 7.5	-
		"	16:12	10 : 1, 5	-
		"	16:42	80 : 1, 8.5	-
Tuesday, April 22, 1986	Cold-partly sunny. Wind: 6 to 14 knots from NW to NNW	VI	10:16	-	MID : 1
		"	10:17	-	MID : 3
		"	10:18	MID : 1, 8	-
		"	10:45	WD/4-S : 1, 8	-
		"	11:24	20-N : 1, 5.5	-
		VII-A	12:40	30-N : 1, 13	-
		"	13:08	15-S : 1, 5.5	-
		"	13:37	10-N : 1, 5	-
Wednesday, April 23, 1986	Cool, sunny Wind: AM - Calm PM-0 to 6 knots from SSW to WNW	VII-A	9:32	-	WD/4-N : 3
		"	9:32	-	MID : 3
		"	9:33	-	WD/4-S : 3
		"	9:42	10-N : 1, 4.5	-
		"	10:12	30-N : 1, 13.5	-
		"	10:28	30-N : 5	-
		"	10:52	30-S : 1, 8	-
		VIII	12:12	40-E : 1, 7	-
		"	12:35	10-E : 1	-
		"	13:05	30-W : 1, 5	-
		VII-B	13:52	20-W : 1, 5.5	-
		"	14:13	50-W : 1, 3, 6.5	-
		"	15:00	25-E : 1, 5	-
		VII-C	15:26	30-W : 1, 6	-
		"	15:47	35-E : 1, 5	-
		"	16:09	30-E : 1, 4	-
Saturday, April 26, 1986	Wind: AM - 6 to 14 knots from NE to SE. PM - 10 to 12 knots from SE.	II	8:41	10 : 1	-
		"	9:04	40 : 1, 7	-
		"	9:24	100 : 1, 10.5	-
		IV-CDN.	9:57	10 : 1, 7.5	-
		"	10:20	40 : 1, 9.5	-
		"	10:42	100 : 1, 10.5	-

APPENDIX I - CHRONOLOGICAL SUMMARY OF CONDUCTED MEASUREMENTS
(Continued)

DATE	WEATHER	SECTION NO.	APPROXIMATE TIME	CURRENT METER DEPLOYMENTS	DROGUE RELEASES
				Lateral Location : Vertical Depth (m)	Lateral Location : Vertical Depth (m)
		IV-U.S.	11:20	10 : 1, 5.5	-
		"	11:48	40 : 1, 9.5	-
		"	12:12	100 : 1, 9.5	-
		V	13:33	WD/4-E : 1, 7.5	-
		"	13:58	MID : 1, 8.5	-
		"	14:22	WD/4-W : 1, 5.5	-
		I	14:59	10 : 1.	-
		"	15:19	40 : 1, 9.5	-
		"	15:43	100 : 1, 11.5	-
Sunday, April 27, 1986	Wind: 6 to 10 knots from SE	I	8:28	-	70 : 1
		"	8:28	-	70 : 7
		II	8:32	-	40 : 1
		"	8:32	-	40 : 7
Tuesday, July 29, 1986	Cool - Cloudy with showers. Wind: Until 4:00 PM - 3 to 8 knots from W to NW. 5:00 PM - 12 knots from N.	I	8:53	100 : 1, 5., 9.5	-
		II	9.43	-	40 : 7
		II	9:45	-	40 : 1
		I	9:46	10 : 1,	-
		"	10:06	40 : 1, 4., 7.5	-
		II	10:52	100 : 1, 5.5, 10.5	-
		"	11:32	40 : 1, 4., 7.5	-
		"	12:16	10 : 1, 4.	-
		IV-CDN.	12:53	10 : 1	-
		"	13:08	40 : 1, 5.5	-
		I	13:22	-	70 : 7
		"	13:23	-	70 : 1
		IV-CDN.	13:51	100 : 1, 5., 9.5	-
		IV-U.S.	14:37	20 : 1, 4.5	-
		"	15:04	40 : 1, 9.5	-
		"	15:36	100 : 1, 5., 10.	-
		V	16:30	WD/4-E : 1, 10.5	-
		"	17:02	MID : 1, 4., 8.	-
		"	17:47	WD/4-W : 1, 7.5	-
Wednesday, July 30, 1986	Warm - partly sunny. Wind: 0 to 10 knots from W to NW	I	8:27	-	75 : 1
		"	8:27	-	75 : 6
		VI	11:35	MID : 1, 3.5, 6.5	-
		II	12:53	-	40 : 1
		"	12:53	-	40 : 6
		VII-A	12:59	WD/4-N : 1, 6.	-
		"	13:22	MID : 1, 6., 12.	-
		"	13:57	15-S : 1, 5.5	-

APPENDIX I - CHRONOLOGICAL SUMMARY OF CONDUCTED MEASUREMENTS

(Continued)

DATE	WEATHER	SECTION NO.	APPROXIMATE TIME	CURRENT METER DEPLOYMENTS	DROGUE RELEASES
				Lateral Location : Vertical Depth (m)	Lateral Location : Vertical Depth (m)
		VII-B	14:27	MID : 1, 3., 6.	-
		"	14:59	25-W : 1, 5.	-
		"	15:29	10-E : 1, 5.	-
		VII-C	16:13	15-E : 1, 5.5	-
		"	16:37	30-E : 1, 4., 7.5	-
		"	17:10	10-W : 1, 2.5	-
Thursday, July 31, 1986	Hot-Sunny. Wind: 0 to 9 knots from S to SW	VI	9:40	-	MID : 3
		"	9:41	-	MID : 1
		"	9:42	MID : 1, 3.5, 6.5	-
		"	10:14	WD/4-S : 1, 7.5	-
		"	10:37	10-N : 1, 4.	-
		VII-A	11:50	35-N : 1, 6.5, 13.	-
		"	12:24	15-N : 1., 9.5	-
		"	12:51	20-S : 1., 7.5	-
		VII-B	13:19	30-E : 1, 3., 6.	-
		"	13:19	-	30-E : 3
		"	13:20	-	30-E : 1
		"	13:57	15-W : 1, 5.	-
		"	14:19	10-E : 1, 4.5	-
		VII-C	15:35	MID : 1, 4.5, 8.5	-
		"	15:37	-	MID : 1
		"	15:38	-	MID : 3
		"	16:08	7-W : 1., 5.	-
		"	16:32	12-E : 1., 8.	-
Friday, August 1, 1986	Warm-Sunny Wind: 3 to 10 knots from NW to NE	I	8:58	100 : 1, 5., 10.	-
		"	9:31	40 : 1, 7.5	-
		"	9:59	10 : 0.75	-
		III-CDN.	10:27	20 : 1, 5.5	-
		"	11:02	60 : 1, 9.	-
		"	11:45	100 : 1, 5., 10.	-
		III-U.S.	12:26	40 : 1, 7.	-
		"	12:55	100 : 1, 5., 9.5	-
		IV-CDN.	13:35	100 : 1, 5., 9.5	-
		"	14:05	50 : 1, 9.5	-
		V	14:41	80-E : 1, 10.5	-
		"	15:19	MID : 1, 4., 8.	-
		"	15:59	220-E : 1, 7.5	-

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
I	21/04																		
	10:24			10	2.5	1.	21	19.8	6.5	9.9	32.3	217.9	18.4	166.2	241.6	5.0	0.0	5.0	5.0
	9:53	8	335 to 25	40	7.	1.	20	88.0	5.7	79.9	96.7	219.9	4.6	208.1	228.4	4.8	0.3	4.1	5.0
	12:12		310	75	11.	1.	30	121.2	4.5	113.5	130.5	221.8	2.7	215.1	226.3	4.7	0.0	4.7	4.8
	26/04																		
	14:59			10	3.	1.	16	33.5	9.6	18.3	54.7	214.4	16.8	177.4	234.6	6.3	0.1	6.3	6.4
	15:19			40	10.	1.	18	72.6	3.3	68.7	79.9	223.6	5.7	208.5	235.0	6.1	0.0	6.1	6.2
	15:43	10 to 12	135	100	12.	1.	17	108.7	4.1	102.3	116.3	223.9	3.4	217.9	231.1	5.9	0.0	5.9	6.0
	29/07																		
	9:46			10	2.	1.	21	7.9	4.1	1.5	18.3	193.0	39.0	109.3	247.2	20.3	0.1	20.3	20.5
	10:06			40	8.	1.	21	99.9	7.6	85.5	113.5	222.7	4.4	212.6	231.5	20.6	0.1	20.3	20.7
	10:17			40	8.	4.	21	85.2	7.6	74.3	96.7	226.7	7.3	214.7	243.0	20.6	0.0	20.6	20.7
	10:29			40	8.	7.5	21	57.0	9.0	40.7	74.3	228.1	11.7	204.6	247.9	20.7	0.1	20.6	20.9
	8:53	8	264 to 309	100	10.	1.	21	123.1	6.9	113.5	141.5	228.8	2.7	221.0	232.5	20.5	0.0	20.5	20.6
	9:05			100	10.	5.	21	111.4	7.2	96.7	119.1	226.2	5.5	211.6	233.6	20.5	0.0	20.5	20.5
	9:16			100	10.	9.5	22	76.8	13.7	57.5	107.9	232.2	10.9	213.3	251.0	20.5	0.0	20.5	20.6

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	1/08																		
	9:59			10	1.5	0.75	17	8.7	3.3	7.1	18.3	221.1	29.1	154.4	257.7	21.4	0.7	21.2	24.2
	9:31			40	8.	1.	14	91.1	4.4	85.5	96.7	227.9	12.7	216.8	269.2	21.1	0.0	21.0	21.1
	9:40			40	8.	7.5	17	64.4	10.6	46.3	79.9	225.1	13.5	210.2	269.2	21.1	0.1	21.0	21.2
	8:58	3 to 6	309	100	10.5	1.	16	118.1	4.7	107.9	124.7	228.4	2.7	221.4	232.2	21.0	0.0	21.0	21.0
	9:07			100	10.5	5.	17	102.6	8.5	91.1	124.7	225.1	4.3	215.4	232.2	21.2	0.8	21.0	24.2
	9:17			100	10.5	10.	14	72.7	12.9	51.9	102.3	229.1	9.3	214.7	245.1	21.0	0.0	21.0	21.1
II	26/04																		
	8:41	6 to 8	45	10	2.5	1.	17	12.9	2.7	7.1	15.5	224.7	53.5	140.4	326.1	7.4	0.7	6.3	8.6
	9:04			40	7.5	1.	15	35.1	9.2	18.3	51.9	228.0	9.8	210.9	237.8	6.1	0.1	6.0	6.3
	9:24			100	11.	1.	17	111.7	4.2	105.1	119.1	226.4	2.4	219.6	229.0	5.7	0.0	5.6	5.7
	29/07																		
	12:16			10	4.5	1.	21	32.7	7.6	23.9	46.3	229.6	9.3	201.8	242.3	21.1	0.4	20.8	22.0
	12:27			10	4.5	4.	20	29.2	6.4	12.7	40.7	238.7	13.2	207.1	256.3	20.9	0.1	20.8	21.1
	11:32			40	8.	1.	24	59.4	13.5	35.1	91.1	227.7	6.3	221.7	243.0	20.3	0.1	20.3	20.5
	11:45			40	8.	4.	21	45.2	7.2	29.5	51.9	231.6	6.6	221.4	244.4	20.8	0.0	20.7	20.8

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	11:56			40	8.	7.5	21	33.2	7.2	23.9	46.3	236.5	19.2	183.7	264.3	20.8	0.0	20.8	20.9
	10:52	7	319	100	11.	1.	21	139.1	5.2	124.7	147.1	231.0	6.6	224.9	239.5	20.3	0.1	20.3	20.6
	11:04			100	11.	5.5	21	120.2	5.2	113.5	130.3	228.0	4.8	217.9	236.0	20.6	0.0	20.6	20.6
	11:16			100	11.	10.5	21	80.4	12.3	57.5	102.3	229.3	6.9	221.4	246.1	20.6	0.0	20.6	20.6
III CDN.	21/04																		
	12:59	5	10	15	6.5	1.	21	59.0	4.4	51.9	65.9	222.8	5.3	212.3	331.1	5.4	0.1	5.2	5.6
	13:38	10		40	8.5	1.	20	64.6	6.9	54.7	77.1	224.6	10.4	208.1	248.9	5.2	0.1	5.0	5.3
	14:12	10	355 to 10	80	10.5	1.	23	116.4	5.3	105.1	124.7	225.6	4.0	216.8	235.0	4.9	0.1	4.8	5.0
	1/08																		
	10:27			20	6.5	1.	16	52.3	4.8	46.3	57.5	238.3	9.7	230.8	269.2	21.9	0.2	21.5	22.2
	10:37			20	6.5	5.5	6	41.6	4.2	35.1	46.3	241.0	6.5	230.8	246.8	21.9	0.1	21.8	21.9
	11:02			60	9.5	1.	21	88.2	5.5	79.9	96.7	223.1	3.1	216.5	226.6	21.3	0.1	21.2	21.4
	11:15			60	9.5	9.	17	63.4	7.5	51.9	85.5	225.1	4.6	213.3	233.6	21.3	0.1	21.2	21.4
	11:45	4 to 6	310	100	10.5	1.	16	118.1	5.5	113.5	130.3	232.3	5.1	221.1	244.8	21.2	0.0	21.1	21.2
	11:54			100	10.5	5.	17	113.5	6.3	102.3	119.1	229.2	6.2	215.1	236.7	21.1	0.1	21.1	21.2
	12:04			100	10.5	10.	18	78.3	17.9	57.5	119.1	227.9	7.8	210.9	245.1	21.1	0.1	21.1	21.2

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN) START TIME (HR:MIN)	WINDS MEASUREMENTS FROM BOAT SPEEDS (knots)	WINDS MEASUREMENTS FROM BOAT DIRECTION FROM (Bearing°)	APPROX. DISTANCE FROM SHORE (m)	APPROXIMATE DEPTH OF RIVER (m)	APPROXIMATE DEPTH OF METER (m)	NO. OF RDGS	CURRENT SPEED (cm/s) MEAN	CURRENT SPEED (cm/s) S.D.	CURRENT SPEED (cm/s) MIN.	CURRENT SPEED (cm/s) MAX.	CURRENT HEADING (Bearing Angle °) MEAN	CURRENT HEADING (Bearing Angle °) S.D.	CURRENT HEADING (Bearing Angle °) MIN.	CURRENT HEADING (Bearing Angle °) MAX.	WATER TEMPERATURE (°C) MEAN	WATER TEMPERATURE (°C) S.D.	WATER TEMPERATURE (°C) MIN.	WATER TEMPERATURE (°C) MAX.
III U.S.	21/04																		
	16:12		5	10	5.5	1.	20	56.7	2.4	51.9	60.3	224.5	5.5	210.9	232.9	4.7	0.0	4.7	4.7
	15:41		5	40	8.	1.	22	86.4	2.8	82.7	91.1	223.8	3.9	213.7	230.4	4.7	0.0	4.7	4.7
	16:42	10	15	80	9.	1.	21	93.5	3.5	88.3	99.5	222.9	3.9	215.8	232.5	4.8	0.1	4.7	4.8
	1/08																		
	12:26			40	7.5	1.	15	86.6	3.1	79.9	91.1	229.7	3.4	224.2	235.0	21.7	0.7	21.5	24.2
	12:36			40	7.5	7.	17	64.7	8.3	51.9	79.9	226.8	13.7	210.6	269.2	21.6	0.0	21.5	21.6
	12:55	10	37	100	10.	1.	16	99.9	13.4	85.5	147.1	229.9	3.4	224.9	236.0	21.6	0.1	21.6	21.8
	13:04			100	10.	5.	18	91.1	5.8	79.9	102.3	226.0	3.6	219.3	233.2	21.7	0.6	21.6	24.2
	13:15			100	10.	9.5	17	66.7	13.4	40.7	91.1	230.5	15.4	213.0	269.2	21.6	0.0	21.6	21.6
IV CDN.	26/04																		
	9:57	CALM		10	8.	1.	19	42.0	5.9	32.3	51.9	203.7	5.3	196.6	214.4	6.6	0.2	6.2	7.1
	10:20			40	10.	1.	16	83.1	3.8	77.1	91.1	205.2	3.3	197.6	210.9	5.9	0.1	5.8	6.2
	10:42	10 to 12	135	100	11.	1.	17	109.1	5.0	99.5	119.1	209.8	2.9	204.3	216.8	5.6	0.1	5.6	5.7
	29/07																		
	12:53			10	1.5	1.	21	12.7	3.5	7.1	18.3	221.9	30.7	169.4	291.2	21.5	0.0	21.5	21.5

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN) START TIME (HR:MIN)	WINDS MEASUREMENTS FROM BOAT SPEEDS (knots)	WINDS MEASUREMENTS FROM BOAT DIRECTION FROM (Bearing°)	APPROX. DISTANCE FROM SHORE (m)	APPROXIMATE DEPTH OF RIVER (m)	APPROXIMATE DEPTH OF METER (m)	NO. OF RDGS	CURRENT SPEED (cm/s) MEAN	CURRENT SPEED (cm/s) S.D.	CURRENT SPEED (cm/s) MIN.	CURRENT SPEED (cm/s) MAX.	CURRENT HEADING (Bearing Angle °) MEAN	CURRENT HEADING (Bearing Angle °) S.D.	CURRENT HEADING (Bearing Angle °) MIN.	CURRENT HEADING (Bearing Angle °) MAX.	WATER TEMPERATURE (°C) MEAN	WATER TEMPERATURE (°C) S.D.	WATER TEMPERATURE (°C) MIN.	WATER TEMPERATURE (°C) MAX.
	13:08			40	6.	1.	21	31.4	4.1	23.9	35.1	214.4	9.2	202.5	224.9	21.5	0.1	21.3	21.7
	13:19			40	6.	5.5	21	37.0	8.0	23.9	51.9	205.9	7.1	199.7	224.9	20.5	0.4	20.3	21.4
	13:51	6	322	100	10.	1.	21	109.5	6.2	96.7	119.1	217.7	4.0	202.5	222.4	20.3	0.0	20.3	20.3
	14:02			100	10.	5.	21	102.0	6.3	91.1	113.5	211.4	8.2	202.5	222.1	20.3	0.0	20.3	20.3
	14:14			100	10.	9.5	21	70.8	9.3	51.9	85.5	211.3	11.7	180.2	223.8	20.3	0.0	20.3	20.3
	1/08																		
	14:05			50	10.	1.	16	85.9	9.7	68.7	96.7	218.5	4.2	208.5	227.3	21.5	0.1	21.4	21.8
	14:14			50	10.	9.5	14	62.7	9.4	46.3	79.9	210.2	9.6	186.5	223.5	21.5	0.0	21.4	21.6
	13:35	6	337 to 352	100	10.	1.	14	118.7	5.6	107.9	124.7	220.8	1.4	218.2	222.8	21.3	0.0	21.3	21.4
	13:43			100	10.	5.	17	114.8	7.8	96.7	124.7	215.3	3.7	210.9	223.5	21.5	0.7	21.3	24.2
	13:52			100	10.	9.5	17	84.8	11.0	68.7	107.9	211.7	7.8	200.4	228.4	21.3	0.0	21.3	21.3
IV U.S.	26/04																		
	11:20			10	6.	1.	19	59.9	4.1	51.9	65.9	224.2	7.5	205.7	235.0	5.2	0.0	5.2	5.3
	11:48	12 to 14	135	40	10.	1.	18	80.7	3.7	74.3	85.5	219.5	4.8	211.6	226.3	5.4	0.1	5.4	5.5
	12:12			100	10.	1.	15	87.9	2.6	85.5	93.9	221.2	3.9	213.7	229.7	5.4	0.0	5.3	5.4

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	29/07																		
	14:37			10	5.	1.	21	41.2	4.7	29.5	46.3	223.6	2.2	217.2	224.9	20.3	0.0	20.3	20.3
	14:48			10	5.	4.5	21	37.2	7.0	29.5	51.9	216.9	9.0	202.5	224.9	20.3	0.0	20.3	20.3
	15:04			40	10.	1.	21	94.3	4.5	85.5	102.3	221.9	2.7	216.8	224.9	20.3	0.0	20.3	20.3
	15:15			40	10.	9.5	21	56.7	9.3	40.7	74.3	225.1	4.2	212.3	233.2	20.8	0.5	20.3	21.2
	15:36	3	343	100	10.5	1.	21	104.2	4.1	96.7	113.5	223.0	2.0	217.9	224.9	20.3	0.0	20.3	20.4
	15:48			100	10.5	5.	21	96.2	5.8	85.5	107.9	217.9	4.4	202.5	224.9	20.3	0.0	20.3	20.3
	15:59			100	10.5	10.	21	61.8	7.9	51.9	79.9	215.7	7.7	202.5	224.9	20.3	0.0	20.3	20.3
V	26/04																		
	13:33			WD/4-E	8.	1.	17	62.1	3.7	54.7	68.7	188.2	2.8	181.9	193.5	6.6	0.1	6.6	6.7
	13:58	12	135	MID	9.	1.	17	111.9	3.4	105.1	119.1	189.9	1.6	187.5	193.5	5.8	0.0	5.8	5.8
	14:22			WD/4-W	6.	1.	18	82.4	4.4	74.3	91.1	195.6	2.3	191.7	199.4	5.8	0.0	5.8	5.8
	29/07																		
	16:30			WD/4-E	11.	1.	21	113.5	5.0	107.9	124.7	196.2	4.8	180.2	202.5	20.3	0.1	20.3	20.8
	16:41			WD/4-E	11.	10.5	21	75.4	7.0	63.1	91.1	194.3	8.5	180.2	202.5	20.3	0.0	20.3	20.5
	17:02	12	5	MID	8.5	1.	22	116.3	4.5	107.9	124.7	190.6	6.8	180.2	199.0	20.4	0.2	20.3	20.8

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	17:16			MID	8.5	4.	21	110.8	4.2	102.3	119.1	191.7	4.3	183.3	198.0	20.8	0.0	20.8	20.8
	17:28			MID	8.5	8.	21	84.4	7.6	68.7	96.7	197.6	6.4	184.4	208.1	20.8	0.0	20.8	20.8
	17:47			WD/4-W	8.	1.	21	113.5	3.1	107.9	119.1	191.4	6.8	180.2	199.0	20.3	0.1	20.3	20.6
	17:58			WD/4-W	8.	7.5	21	80.4	8.3	63.1	96.7	191.8	8.3	178.8	202.5	20.3	0.0	20.3	20.3
	1/08																		
	14:41			80-E	11.	1.	15	115.7	4.1	107.9	119.1	197.8	3.2	191.4	204.3	21.4	0.0	21.4	21.5
	15:02			80-E	11.	10.5	16	69.1	7.5	57.5	79.9	202.2	11.1	184.0	224.2	21.4	0.0	21.4	21.5
	15:19	4 to 10	350	MID	8.5	1.	15	116.5	3.6	113.5	124.7	197.2	2.2	194.1	200.8	21.4	0.0	21.4	21.5
	15:28			MID	8.5	4.	16	111.1	3.5	107.9	119.1	193.8	4.5	183.7	202.2	21.4	0.0	21.4	21.4
	15:37			MID	8.5	8.	20	80.7	7.6	68.7	96.7	198.8	4.2	188.9	204.6	21.4	0.0	21.4	21.4
	15:59			220-E	8.	1.	17	112.8	2.7	107.9	119.1	196.4	2.7	191.4	201.1	21.5	0.0	21.5	21.5
	16:09			220-E	8.	7.5	8	77.8	9.4	63.1	91.1	194.4	6.6	186.8	207.1	21.5	0.0	21.5	21.5
VI	22/04																		
	11:24	6		20-N	6.	1.	22	29.9	2.2	26.7	35.1	-	-	-	-	4.8	0.0	4.8	4.8
	10:18	8 to 25	325 to 340	MID	8.5	1.	23	40.8	2.9	35.1	46.3	-	-	-	-	4.7	0.0	4.7	4.8
	10:45			WD/4-S	8.5	1.	22	52.0	2.2	46.3	54.7	-	-	-	-	4.7	0.0	4.7	4.7

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS
(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	30/07																		
	11:35	4	264	MID	7.	1.	17	54.2	2.8	51.9	57.5	119.2	5.8	105.5	131.3	21.0	0.0	21.0	21.1
	11:44			MID	7.	3.5	17	55.9	2.6	51.9	57.5	112.3	1.8	107.9	113.2	20.3	0.0	20.3	20.3
	11:53			MID	7.	6.5	19	44.2	5.3	35.1	51.9	109.4	3.6	102.7	113.2	20.3	0.0	20.3	20.3
	31/07																		
	10:37			10-N	4.5	1.	16	28.8	5.0	23.9	40.7	115.4	6.8	103.8	129.9	21.3	0.0	21.3	21.3
	10:46			10-N	4.5	4.	17	26.5	7.4	18.3	40.7	117.7	10.6	94.7	134.5	21.3	0.0	21.3	21.3
	9:42	CALM		MID	7.	1.	16	53.7	2.7	51.9	57.5	122.8	15.3	114.6	179.8	21.2	0.0	21.2	21.2
	9:51			MID	7.	3.5	17	50.6	2.4	46.3	51.9	114.9	2.2	110.7	118.8	21.2	0.0	21.2	21.2
	10:00			MID	7.	6.5	17	37.7	4.5	29.5	46.3	114.7	7.5	104.8	127.1	21.2	0.0	21.2	21.2
	10:14			WD/4-S	8.	1.	16	63.1	0.0	63.1	63.1	119.4	1.6	117.0	122.6	21.2	0.0	21.2	21.3
	10:24			WD/4-S	8.	7.5	17	44.3	4.8	35.1	51.9	110.1	5.4	99.6	119.1	21.2	0.0	21.2	21.3
VII -A	22/04																		
	13:37			10-N	5.5	1.	23	35.7	1.2	35.1	37.9	-	-	-	-	4.9	0.0	4.9	4.9
	12:40			30-N	13.5	1.	22	39.7	1.4	37.9	40.7	-	-	-	-	5.0	0.0	4.9	5.0
	13:08			15-S	6.	1.	22	32.3	1.7	29.5	35.1	-	-	-	-	4.9	0.0	4.9	4.9

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	23/04																		
	9:42			10-N	5.	1.	19	35.8	1.8	32.3	37.9	123.9	3.9	117.4	133.4	4.8	0.0	4.7	4.8
	10:12			30-N	14.	1.	15	42.6	1.4	40.7	43.5	118.8	2.1	116.0	121.9	4.8	0.0	4.8	4.8
	10:28			30-N	14	5.	16	39.8	1.3	37.9	40.7	123.0	2.9	118.8	130.6	4.8	0.1	4.7	4.8
	10:52	1	300	30-S	8.5	1.	15	34.4	1.3	32.3	35.1	121.3	4.6	113.9	130.6	4.9	0.0	4.9	4.9
	30/07																		
	12:59	0 to 9	268 to 328	WD/4-N	7.	1.	16	51.2	1.9	46.3	51.9	128.0	3.1	122.6	132.4	21.1	0.1	21.1	21.2
	13:08			WD/4-N	7.	6.	19	42.1	6.1	23.9	51.9	124.4	4.4	112.5	132.0	21.1	0.0	21.1	21.1
	13:22			MID	13.	1.	18	52.8	2.1	51.9	57.5	118.4	3.4	112.5	124.0	21.2	0.0	21.2	21.2
	13:33			MID	13.	6.	17	50.6	2.4	46.3	51.9	122.7	4.3	115.3	133.8	21.2	0.1	21.1	21.2
	13:42			MID	13.	12.	17	27.5	6.5	18.3	40.7	121.8	4.4	111.8	130.3	21.2	0.0	21.1	21.2
	13:57			15-S	6.	1.	17	40.0	1.9	35.1	40.7	118.8	7.0	113.2	130.3	20.4	0.3	20.3	21.3
	14:09			15-S	6.	5.5	17	30.2	3.4	23.9	35.1	121.1	12.4	106.9	151.6	20.3	0.0	20.3	20.3
	31/07																		
	12:24			15-N	10.	1.	17	54.5	2.9	51.9	57.5	117.8	3.2	110.0	124.0	21.4	0.0	21.4	21.4
	12:33			15-N	10.	9.5	17	40.0	5.6	35.1	57.5	119.9	6.0	106.9	132.7	21.4	0.0	21.4	21.4

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	11:50	2 to 6	223	35-N	13.5	1.	17	52.2	1.4	51.9	57.5	117.6	3.1	112.1	121.9	21.3	0.0	21.3	21.3
	11:59			35-N	13.5	6.5	17	46.6	3.1	40.7	51.9	122.8	4.0	116.7	131.3	21.3	0.0	21.3	21.3
	12:08			35-N	13.5	13.	16	33.0	4.5	29.5	46.3	130.4	4.7	119.8	136.6	21.3	0.0	21.3	21.3
	12:51			20-S	8.	1.	16	41.8	2.3	40.7	46.3	122.2	3.6	116.3	131.0	21.4	0.0	21.4	21.5
	13:00			20-S	8.	7.5	19	31.3	3.8	23.9	40.7	125.7	5.7	112.8	132.4	21.4	0.0	21.4	21.4
VII -B	23/04																		
	13:52	CALM		20-W	6.	1.	15	12.1	2.2	9.9	15.5	40.0	7.3	19.0	47.9	5.2	0.1	5.2	5.4
	14:13			50-W	7.	1.	33	12.5	6.0	1.5	21.1	51.4	47.3	-45.8	211.6	5.4	0.1	5.2	5.5
	15:00			25-E	5.5	1.	16	7.1	3.4	1.5	12.7	86.7	80.2	-79.6	224.9	5.5	0.1	5.4	5.6
	30/07																		
	14:59			25-W	5.5	1.	17	10.7	5.2	1.5	18.3	27.8	16.9	1.5	59.1	21.3	0.1	21.3	21.4
	15:09			25-W	5.5	5.	17	12.7	5.6	1.5	23.9	37.1	14.4	20.0	68.5	21.3	0.0	21.3	21.3
	14:27			MID	6.5	1.	17	23.2	4.8	12.7	35.1	30.9	7.3	23.1	43.4	20.3	0.0	20.3	20.3
	14:36			MID	6.5	3.	17	30.5	4.5	23.9	40.7	28.3	6.8	20.7	39.2	20.3	0.0	20.3	20.3
	14:46			MID	6.5	6.	17	19.6	3.7	12.7	23.9	40.8	10.5	23.8	60.1	20.3	0.0	20.3	20.3
	15:29	2 to 9	326	10-E	5.5	1.	17	27.5	8.6	12.7	35.1	35.7	11.9	21.0	68.2	21.5	0.1	21.4	21.5

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS

(Continued)

SEC. NO.	DATE (DY/MN) START TIME (HR:MIN)	WINDS MEASUREMENTS FROM BOAT SPEEDS (knots)	WINDS MEASUREMENTS FROM BOAT DIRECTION FROM (Bearing°)	APPROX. DISTANCE FROM SHORE (m)	APPROXIMATE DEPTH OF RIVER (m)	APPROXIMATE DEPTH OF METER (m)	NO. OF RDGS	CURRENT SPEED (cm/s) MEAN	CURRENT SPEED (cm/s) S.D.	CURRENT SPEED (cm/s) MIN.	CURRENT SPEED (cm/s) MAX.	CURRENT HEADING (Bearing Angle °) MEAN	CURRENT HEADING (Bearing Angle °) S.D.	CURRENT HEADING (Bearing Angle °) MIN.	CURRENT HEADING (Bearing Angle °) MAX.	WATER TEMPERATURE (°C) MEAN	WATER TEMPERATURE (°C) S.D.	WATER TEMPERATURE (°C) MIN.	WATER TEMPERATURE (°C) MAX.
	15:39			10-E	5.5	5.	17	26.5	6.6	18.3	40.7	40.9	9.4	20.3	62.9	21.4	0.0	21.4	21.5
	31/07																		
	13:57			15-W	5.5	1.	15	17.6	3.6	12.7	23.9	37.4	19.1	2.9	70.6	21.5	0.0	21.5	21.5
	14:05			15-W	5.5	5.	17	10.4	3.5	7.1	18.3	41.3	32.4	-21.0	87.0	21.5	0.0	21.5	21.5
	13:19	4 to 9	176	30-E	6.5	1.	15	33.2	3.5	29.5	40.7	41.5	7.6	27.7	54.2	21.4	0.0	21.4	21.5
	13:27			30-E	6.5	3.	17	36.7	4.3	29.5	46.3	33.6	5.9	19.6	41.6	21.4	0.0	21.4	21.4
	13:36			30-E	6.5	6.	18	31.4	5.1	23.9	40.7	41.8	7.0	28.4	54.2	21.4	0.0	21.4	21.4
	14:19			10-E	5.	1.	17	30.2	8.4	18.3	51.9	33.6	9.7	19.3	48.6	21.6	0.2	21.5	22.5
	14:29			10-E	5.	4.5	17	24.6	5.2	18.3	35.1	44.8	13.4	25.6	74.4	21.6	0.0	21.5	21.6
VII -C	23/04																		
	15:26	0 to 5	245	30-W	6.5	1.	16	51.2	1.6	49.1	51.9	170.3	5.1	161.7	178.4	5.3	0.0	5.3	5.3
	15:47			35-E	5.5	1.	17	52.9	2.4	49.1	54.7	168.1	2.7	162.7	173.9	5.3	0.0	5.3	5.3
	16:09	0 to 5	290 to 305	30-E	4.5	1.	16	52.3	2.9	43.5	54.7	168.9	3.3	162.4	172.5	5.4	0.1	5.3	5.4
	30/07																		
	17:10			10-W	3.	1.	17	30.2	5.6	18.3	40.7	182.6	12.3	157.2	204.6	21.6	0.1	21.5	21.9
	17:30			10-W	3.	2.5	17	31.1	11.0	12.7	51.9	184.9	18.6	155.4	227.3	21.6	0.1	21.5	21.7

APPENDIX II: STATISTICAL SUMMARY OF CURRENT METER MEASUREMENT RESULTS
(Continued)

SEC. NO.	DATE (DY/MN)	WINDS MEASUREMENTS FROM BOAT		APPROX. DISTANCE FROM SHORE	APPROXIMATE DEPTH		NO. OF RDGS	CURRENT SPEED (cm/s)				CURRENT HEADING (Bearing Angle °)				WATER TEMPERATURE (°C)			
	START TIME (HR:MIN)	SPEEDS (knots)	DIRECTION FROM (Bearing°)	(m)	OF RIVER (m)	OF METER (m)		MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.	MEAN	S.D.	MIN.	MAX.
	16:37			30-E	8.	1.	17	54.2	2.8	51.9	57.5	172.7	7.2	156.8	183.3	21.5	0.0	21.5	21.5
	16:46			30-E	8.	4.	17	51.6	3.1	46.3	57.5	172.5	7.7	162.4	187.2	21.5	0.0	21.5	21.5
	16:57			30-E	8.	7.5	17	36.1	3.6	29.5	40.7	175.7	11.8	154.7	193.8	21.5	0.0	21.5	21.5
	16:13	6 to 10	320	15-E	6.	1.	17	55.5	2.8	51.9	57.5	172.6	7.9	157.9	180.2	21.5	0.0	21.5	21.5
	16:23			15-E	6.	5.5	17	45.0	10.6	23.9	57.5	167.5	10.9	152.6	180.2	21.5	0.0	21.5	21.5
	31/07																		
	16:08			7-W	5.5	1.	15	37.7	5.1	29.5	46.3	180.4	6.2	171.1	190.0	21.7	0.0	21.7	21.7
	16:17			7-W	5.5	5.0	17	28.2	8.3	18.3	40.7	179.4	9.5	163.1	200.4	21.7	0.0	21.7	21.7
	15:35	3	185	MID	9.	1.	19	50.7	2.3	46.3	51.9	178.6	5.7	169.0	191.4	21.6	0.1	21.6	21.8
	15:45			MID	9.	4.5	17	47.3	3.0	40.7	51.9	179.0	5.2	170.4	188.2	21.6	0.0	21.6	21.6
	15:54			MID	9.	8.5	17	38.4	4.5	35.1	46.3	192.9	16.2	177.0	229.7	21.6	0.0	21.6	21.7
	16:32	6 to 9	185	12-E	8.5	1.	15	52.3	3.3	46.3	57.5	176.8	5.1	170.8	186.1	21.7	0.0	21.7	21.7
	16:41			12-E	8.5	8.	16	39.3	6.0	29.5	51.9	174.9	12.0	132.4	183.0	21.7	0.0	21.7	21.7
VIII	23/04																		
	13:05	6	200	30-W	5.5	1.	15	13.1	5.7	1.5	21.1	179.7	4.8	172.2	185.8	5.6	0.1	5.5	5.8
	12:12	CALM		40-E	7.5	1.	16	23.2	1.3	21.1	23.9	183.5	6.7	174.3	199.0	5.4	0.1	5.3	5.5
	12:35	CALM		10-E	2.	1.	17	13.7	3.6	7.1	18.3	180.6	15.4	143.5	206.0	5.6	0.1	5.5	5.7

LEGEND: 30-W means 30 m from West Shore
MID means at mid river

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Polysar @ 1 m Depth

Date: April 27/86
Wind: SE @ 6 → 10 knots

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION I (RELEASE)	68.	8:28			
			11	2,105.	3.2
II	80.	8:39			
			13	3,925.	5.0
III	70.	8:52			
			6	2,220.	6.2
IV	130.	8:58			
			30	4,820.	2.7
Buoy R58	150.	9:28			
			24	5,015.	3.5
South-end Shell Dock	130.	9:52			
			33	6,990.	3.5
Range Light	140.	10:25			
			31	6,170.	3.3
South Tip Stag Island	200.	10:56			
Sec. I → South-end Shell Dock			84	18,085.	3.59
South-end Shell Dock → South Tip Stag Island			64	13,160.	3.43
Sec. I → South Tip Stag Island			148	31,245.	3.52

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Polysar @ 1 m Depth

Date: July 29/86
Wind: NW (0 → 5 km/hr)

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION I (RELEASE)	70.	13:23	9	2,105.	3.9
II	70.	13:32	17	3,925.	3.8
III	70.	13:49	8	2,220.	4.6
IV	60.	13:57	20	4,820.	4.0
Buoy R58	2 m east of buoy	14:17	23	5,015.	3.6
South-end of Shell Dock	130.	14:40	26	6,210.	4.0
SECTION V	Mid - Channel	15:06	33	6,950.	3.5
South-end of Stag Island	Mic- Channel	15:39			
Sec. I → South-end of Shell Dock			77	18,085.	3.91
South-end of Shell Dock → South-end Stag Island			59	13,160.	3.72
Sec. I → South-end Stag Island			136	31,245	3.83

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Polysar @ 1 m Depth

Date: July 30/86
Wind: W 0 → 5 km/hr

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION I (RELEASE)	75.	8:27	8	2,105.	4.4
II	90.	8:35	15		
Just u/s of Dow's Dock /Drogue moved from 20 → 40 m from shore		8:50	6	3,925.	3.1
SECTION III	50.	8:56	8	2,220.	4.6
IV	60.	9:04	22	4,820.	3.7
Buoy R58	70.	9:26	22	5,015.	3.8
South-end of Shell Dock	110.	9:48	27	6,210.	3.8
SECTION V	Mid-Channel	10:15	33	6,950.	3.5
South-tip Stag Island	Mid-Channel	10:48			
Sec. I → South-end of Shell Dock			81	18,085.	3.72
South-end of Shell Dock → South-end of Stag Island			60	13,160.	3.66
Sec. I → South-end of Stag Island			141	31,245.	3.69

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Polysar @ 7 m Depth

Date: April 27/86
Wind: SE @ 6 → 10 knots

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION I (RELEASE)	68.	8:28	13	2,105.	2.7
II	80.	8:41	12	3,925.	5.5
III	80.	8:53	21	2,220.	1.8
IV	100.	9:14	31	4,820.	2.6
Buoy R58	70. (70 moved to 90)	9:45 (10:01)	35	5,015.	2.4
South-end Shell Dock	40.	10:20	59	6,990.	2.0
Range Light	50.	11:19	44	6,170.	2.3
South Tip Stag Island	100.	12:03			
Sec. I → South-end Shell Dock			112	18,085.	2.69
South-end Shell Dock → South Tip Stag Island			103	13,160.	2.13
Sec. I → South Tip Stag Island			215	31,245.	2.42

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Polysar @ 7 m Depth

Date: July 29/86
Wind: NW 0 → 5 km/hr

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION I (RELEASE)	70.	13:22			
			11	2,105.	3.2
II	100.	13:33			
			18	3,925.	3.6
III	70.	13:51			
			9	2,220.	4.1
IV	70.	14:00			
			26	4,820.	3.1
Buoy R58	40	14:26			
			35	5,015.	2.4
South-end of Shell Dock	50.	15:01			
			19		
Just north Stag Island/Drogue moved 20 m further out after bottoming out.		15:20		6,210.	2.3
			27		
SECTION V	30	15:47			
			38	6,950.	3.0
South-end of Stag Island/ (Removed after dragging on bottom) Movement too slow!	25	16:25			
Sec. I → South-end of Shell Dock			99	18,085.	3.04
South-end of Shell Dock → South-end Stag Island			84	13,160.	2.61
Sec. I → South-end Stag Island			183	31,245	2.85

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Polysar @ 6 m Depth

Date: July 30/86
Wind: NW 0 → 5 km/hr

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION I (RELEASE)	75.	8:27	9	2,105.	3.9
II	100.	8:36	17	3,925.	3.8
III	70.	8:53	8	2,220.	4.6
IV	70.	9:01	22	4,820.	3.7
Buoy R58	50 (halfway between shore and buoy).	9:23	28	5,015.	3.0
South-end of Shell Dock	60.	9:51	31	6,210.	3.3
SECTION V	50	10:22	38	6,950.	3.0
South-tip of Stag Island	50	11:00			
Sec. I → South-end of Shell Dock			84	18,085.	3.59
South-end of Shell Dock → South-end Stag Island			69	13,160.	3.18
Sec. I → South-end Stag Island			153	31,245	3.40

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Dow @ 1 m Depth

Date: April 27/86
Wind:

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION II (RELEASE)	40.	8:32			
			26	3,925.	2.5
III	80.	8:58			
			9	2,220.	4.1
IV	130.	9:07			
				4,820.	
Buoy R58	140				
			35	5,015.	4.7
South-end of Shell Dock	110.	9:42			
			30	6,210.	3.5
SECTION V	160	10:12			
			41	8,955.	3.6
South Stag Island Shl. Light	200	10:53			
Sec. II → South-end of Shell Dock			70	15,980.	3.80
South-end of Shell Dock → South Stag Island Shl. Light			71	15,165.	3.56
Sec. II → South Stag Island Shl. Light			141	31,145	3.68

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Dow @ 1 m Depth

Date: July 29/86
Wind: NW

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION II (RELEASE)	40.	9:45	23	3,925.	2.8
III	50.	10:08	9	2,220.	4.1
IV	60.	10:17	21	4,820.	3.8
Buoy R58	60.	10:38	22	5,015.	3.8
South-end Shell Dock	120.	11:00	30	6,210.	3.5
V	Mid-Channel	11:30	33	6,950.	3.5
South Tip Stag Island	Mid-Channel	12:03			
Sec. II → South-end Shell Dock			75	15,980.	3.55
South-end Shell Dock → South-end Stag Island			63	13,160.	3.48
Sec. II → South-end Stag Island			138	29,140.	3.52

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Dow @ 1 m Depth

Date: July 30/86
Wind: NW 10 → 15 km/hr

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION II (RELEASE)	40.	12:53			
Just North of Dow Dock/Moved to 40 m from shore			22	3,925.	3.0
SECTION III	50.	13:15			
			9	2,220.	4.1
IV	70.	13:24			
			22	4,820.	3.7
Buoy R58	50.	13:46			
			25	5,015.	3.3
South-end Shell Dock	30.	14:11			
			30	6,210.	3.5
SECTION V	Mid-Channel	14:41			
			31	6,950.	3.7
South-end Stag Island	60.	15:12			
Sec. II → South-end Shell Dock			78	15,980.	3.41
South-end Shell Dock → South-end Stag Island			61	13,160.	3.60
Sec. II → South-end Stag Island			139	29,140.	3.49

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Dow @ 7 m Depth

Date: April 27/86
Wind:

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION II (RELEASE)	40.	8:32			
			33	3,925.	2.0
III	70.	9:05			
				2,220.	
IV (Drogue Sunk by Current)			93	12,000.	2.5
660 m south of South-end shell dock	80.	10:38			
(Drogue Sunk & Lost)					
SECTION II - 660 m south of south-end shell dock			126	18,145.	2.40

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Dow @ 7 m Depth

Date: July 29/86
Wind: NW

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION II (RELEASE)	40.	9:43			
			24	3,925.	2.7
III	50.	10:07			
			12	2,220.	3.1
IV	40.	10:19			
Between Section IV and Buoy R58/ Drogue Grounded - Moved to 32' depth and rope shortened 1 m (handling time = 6 min.)			31	4,820.	2.6
Buoy R58	40	10:56			
			30	5,015.	2.9
South-end Shell Dock	70	11:26			
			29		
Near Pimec Oil Boom U/S of Stag Island/Pulled to avoid collision	30	11:55			
Sec. II → South-end Shell Dock			97	15,980.	2.75

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Drogue Study Results
North Boundary of Dow @ 6 m Depth

Date: July 30/86
Wind: NW 10 → 15 km/hr

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (ft.)	Travel Velocity (ft/s m/s)
SECTION II (RELEASE)	40.	12:53	5		
Along Dow Property/Drogue Dragging, Moved out to 50 m.	40 → 50	12:58	15	3,925.	3.3
III	60.	13:13	10	2,220.	3.7
IV	60.	13:23	27	4,820.	3.0
Buoy R58	Halfway between buoy and shore	13:50	25	5,015.	3.3
South-end Shell Dock	50	14:15	30	6,210.	3.5
SECTION V	Mid-Channel	14:45	35	6,950.	3.3
South-end Stag Island	Mid-Channel	15:20			
Sec. II → South-end Shell Dock			82	15,980.	3.25
South-end Shell Dock → South-end Stag Island			65	13,160.	3.37
Sec. II → South-end Stag Island			147	29,140.	3.30

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from St. Clair River to
Johnston Channel (@ 1 m depth)

Date: April 22/86
Wind: Ave. From NNW @ 14 knots
@ Section IV @ 10:00 AM

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VI (RELEASE)	@ Mid-Channel	10:17	113	3,370.	0.497
S1	@ Approx. ¼ W from East	12:10	(Unknown)	310.	
S3 (Retrieved)	Grounded on East Shore	14:30			

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from St. Clair River Towards
Johnston Channel @ 1 m depth

Date: July 31/86
Wind: CALM

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VI (RELEASE)	Mid-Stream	9:41			
S3/Found Snagged, Travel Time not valid	At east bank	17:58			

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from St. Clair River to
Johnston Channel (@ 3 m depth)

Date: April 22/86
Wind: Ave. From NNW @ 14 knots
@ Section VI @ 10:00 AM

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VI (RELEASE)	@ Mid-Channel	10:16	114	3,370.	0.493
S1	@ Mid-Channel	12:10	122	2,750.	0.376
S2	'Towards' East Side	14:12	32	900.	0.469
S4	20m from North-East Shore ('Near')	14:44	56	1,330.	0.396
SECTION VII A	1/6 W from North Shore	15:40	5	140.	0.467
S10 (@ Approx. West Bank of Johnston Channel)	1/6 W from North Shore	15:45	10	240.	0.400
S11 (@ South-East 'Corner' of River Junction) (Retrieved)	Caught Near East Shore	15:55			
SECTION VI → S10			329 (5.48hrs)	8,490.	1.41 0.430

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from St. Clair River towards
Johnston Channel (@ 3 m depth)

Date: July 31/86
Wind: CALM

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VI (RELEASE)	Mid-Stream	9:40	95	2,650.	0.465
S21	30 from east shore	11:15			
Lost					

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from Section VII-A to
S9, @ 3 m Depth

Date: April 23/86
Wind: WNW @ < 2 knots @ Section VII-A
@ 9:30 AM To Calm Throughout Day

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VII-A (RELEASE)	¼* W from North Shore	9:32	9	140.	0.259
S10	~¼*W from North shore	9:41	8	120.	0.250
S12		9:49	119	1,440.	0.202
S6	20 m from North Shore (Water depth ~ 6 m)	11:48	4	70.	0.292
S7	moved to Mid-Channel (~30m from NE Shore)	11:52	98	1,280.	0.218
S9 (Retrieved)	Mid-Channel	13:30			
S8 → D/S (Water Became Much More Trubid)					
S12 → S9			221 (3.68 hr)	2,790.	0.690 0.210

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from Section VII-A to
East Shore of Junction, @ 3 m Depth

Date: April 23/86
Wind: WNW @ < 2 knots @ Section VII-A
@ 9:30 To Calm Throughout Day

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VII-A (RELEASE)	Mid-Channel	9:32	9	140.	0.259
S10	Near Mid-Channel	9:41	(Unknown)	120.	
Near centre line of Junction (Retrieved)	Found Stuck ~50m from East Shore	11:40			

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Johnston Channel - From just u/s of
Johnston Channel (Section VII-A) to S5, @ 3 m Depth

Date: April 23/86
Wind: WNW @ < 2 knots @ Section VII-A
@ 9:30 To Calm Throughout Day

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VII-A (RELEASE)	¾* W from North Shore	9:33	14	140.	0.167
S10	~30m from South Reed Line	~ 9:47	5	180.	0.600
S11	Near Mid-Channel	9:52			
Approx. ½ Mile D/S of S11		10:15	91	2,510.	0.460
S5 (Retrieved)	Mid-Channel	11:23			
S11 → S5			91 (1.52 hr)	2,510.	1.51 0.460

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from Johnston Channel
Towards Sydenham River @ 1 m depth.

Date: July 31/86
Wind:

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VII-B (RELEASE)	Mid-Stream	13:20	113	2,100.	0.310
S22/Retrieved	Mid-Stream	15:13			

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Chenal Ecarte - from Johnston Channel
Towards Sydenham River @ 3 m depth.

Date: July 31/86
Wind:

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s m/s)
SECTION VII-B (RELEASE)	Mid-Stream	13:19	115	2,260.	0.328
S23 (@ Marker XE 52)/ (Retrieved)	1/3 Width from north Shore	15:14			

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Johnston Channel - from Chenal Ecarte
Towards Lake St. Clair @ 1 m depth.

Date: July 31/86
Wind:

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (~~ft/s~~ m/s)
SECTION VII-C (RELEASE)	Mid-Stream	15:37			
SECTION VII-C/Pole-only returned to boat by fisherman (found lying-down about 1 km d/s along west shore)		16:24			

APPENDIX III - SUMMARY OF DROGUE MEASUREMENT RESULTS

Johnston Channel - from Chenal Ecarte
Towards Lake St. Clair @ 3 m depth.

Date: July 31/86
Wind:

LOCATION/Comments	Distance from Shore (m)	Recording Time (hr:min)	Travel Time (min)	Travel Distance (m)	Travel Velocity (ft/s [✓ m/s])
SECTION VII-C (RELEASE)	Mid-Stream	15:38	86	2,090.	0.405
S5/Retrieved	Mid-Stream	17:04			

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